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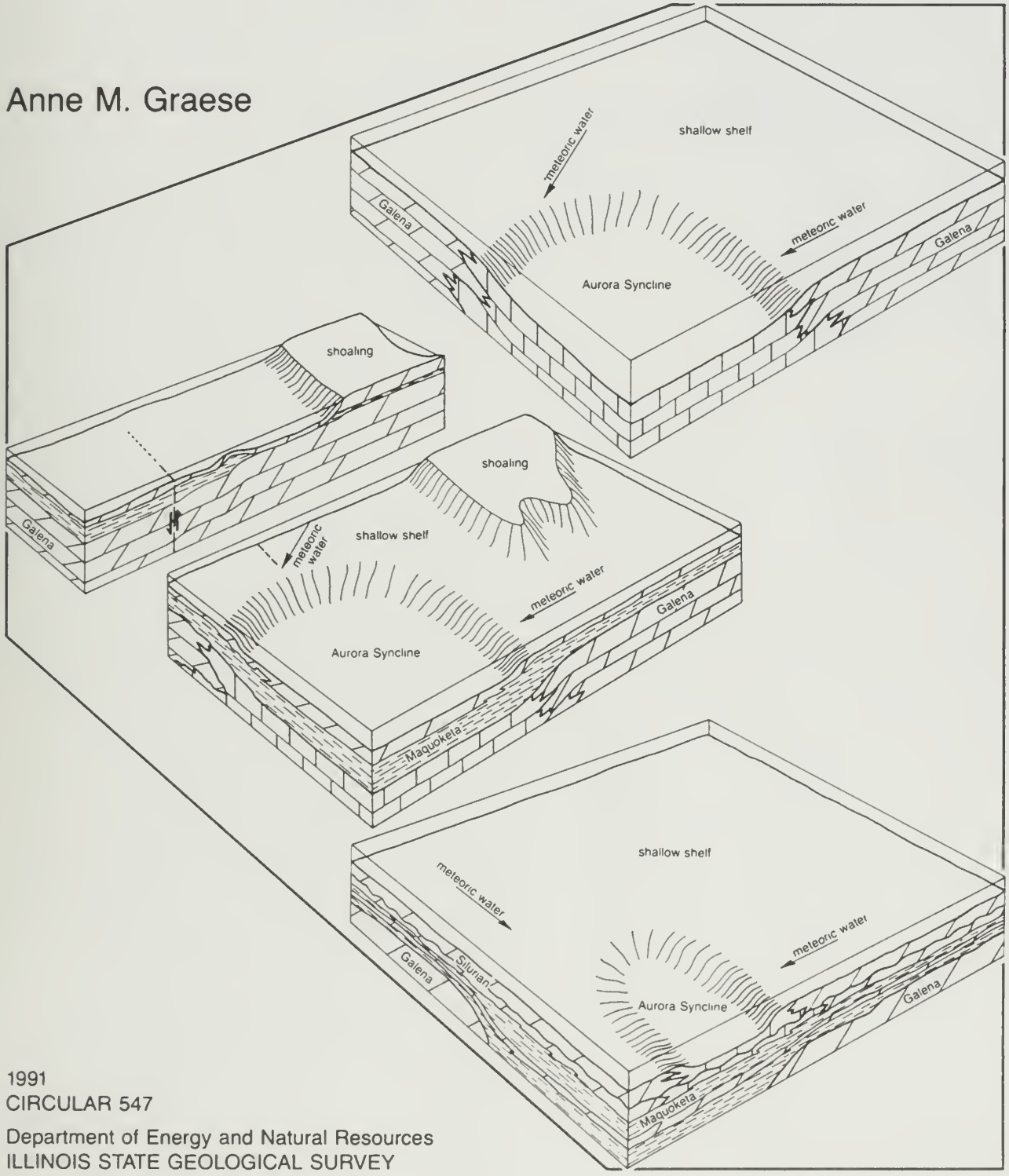
Facies Analysis of the Ordovician Maquoketa Group and Adjacent Strata in Kane County, Northeastern Illinois

Anne M. Graese



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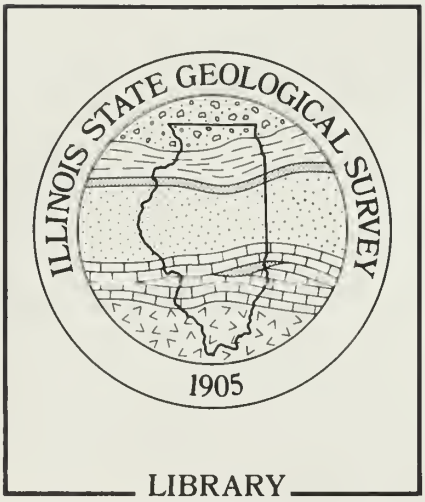

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ABSTRACT

Detailed lithofacies analysis in Kane and surrounding counties was based on study of 30 cores, more than 500 water well records, and 150 sets of well cuttings. The mapping indicates subtle paleostructural influences on deposition and diagenesis in the Ordovician Platteville, Galena, and Maquoketa Groups, and the lower Silurian formations in northeastern Illinois. Focus in this report is mainly on structural influences on lithofacies in the Maquoketa. Diagenetic changes that have been recognized in overlying and underlying carbonate units may also be indicators of paleotopography and/or paleostructure.

The Maquoketa Group in northeastern Illinois consists of shales eroded from the distant Appalachian Mobile Belt to the east of the study area, and biogenic carbonate rocks deposited in situ on a slowly subsiding, stable, shallow shelf in an environment that ranged from subtidal to intertidal in a shallow epicontinental sea. Two shallowing-upward cycles can be identified in the Maquoketa in the study area of Kane and surrounding counties. These rock cycles are characterized by calcareous, olive-gray shale at the base grading upward to dolomitized packstone and coarse crinoidal-bryozoan skeletal grainstone on paleostructural highs. In some places, thin, laminated supratidal deposits and oxidized green and red shales may be present at the top of the rock cycles. These shoaling cycles may be attributed to a combination of eustatic sea-level changes and local, subtle, structural control superimposed on a slightly irregular paleotopographic surface.

The thickness and distribution of the coarse-grained carbonate bodies in the Maquoketa Group appear to be controlled by the paleostructure and paleotopography of the underlying Galena Group. Grainstone shoals were deposited along structural highs while shales and thin beds of fine grained, more shaly carbonates were deposited along structural lows. Dolomitization of the Maquoketa and underlying Platteville and Galena carbonate rocks was also concentrated along paleostructural highs within the zone of freshwater-seawater mixing; low areas (Aurora Syncline) were apparently removed from the influence of freshwater. Small-scale faults, perhaps syndepositional, may have subtly influenced facies and diagenetic patterns in the Ordovician and Silurian units.

A conceptual model was constructed to explain the facies relationships and depositional history of these Ordovician and Silurian rocks.

INTRODUCTION

An area of northeastern Illinois, approximately 40 miles west of the metropolitan Chicago area, is the focus of this report. Geographic coverage includes all of Kane County, the western tier of townships in Du Page County, the northern tier of townships in Kendall County, the eastern two tiers of townships in De Kalb County, T37N, R9E of Will County, and T41-42N, R9E of Cook County (fig. 1). This study area was selected for feasibility studies of an area in northeastern Illinois for a project proposed by the U.S. Department of Energy—the Superconducting Super Collider (SSC), a proton accelerator.

Illinois proposed a site (State of Illinois 1987) adjacent and west of the Fermi National Accelerator Laboratory near Batavia. As an integral part of the siting study, 30 holes were cored in the study area from the bedrock surface to total depths within the Platteville and Galena Groups (Middle Ordovician) and several down to the Ancell Group (Kempton et al. 1985, 1987a, 1987b, Curry et al. 1988, Graese and Kolata 1985, Graese 1988, Graese et al. 1988). These cores provide the most complete information available. Drilling records and cuttings from water wells and surface exposures in the area also were used in the study to provide a countywide assessment.

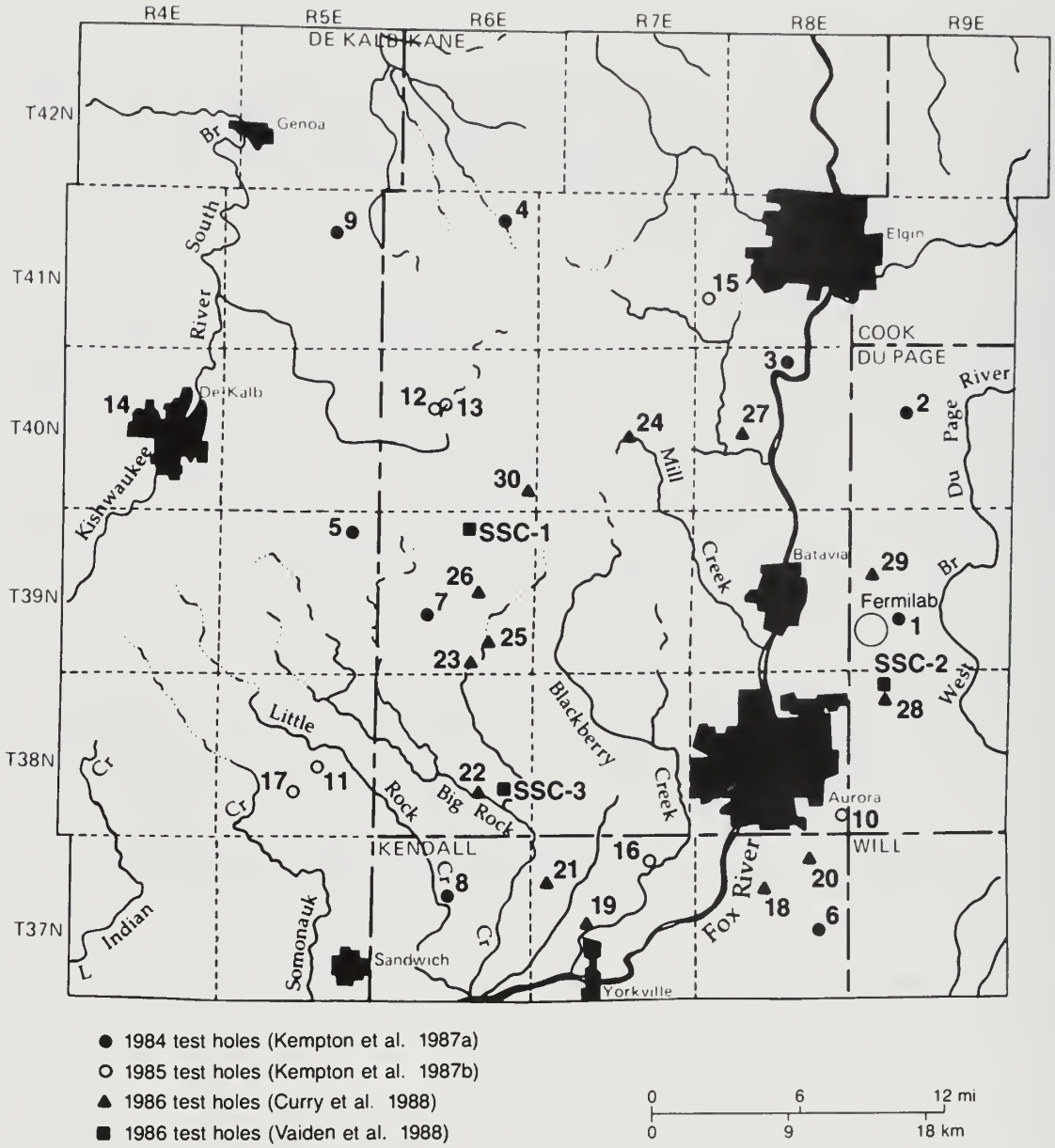

Figure 1 Study area showing selected towns, streams, and test boring locations (modified from Graese et al. 1988).

Focus in this report is primarily on the Maquoketa Group, which shows the most variability in lithofacies; the overlying Silurian and underlying Galena-Platteville are the bounding carbonate units to the Maquoketa. The primary objectives of this report on the Ordovician and lower Silurian strata in the study area of Kane and surrounding counties were to

- compile available drill-hole data on the Platteville, Galena, and Maquoketa Groups, and the basal Silurian formations; construct maps and cross sections of the rocks within the 36-township study area shown in figures 1 and 2.
- evaluate the stratigraphy, sedimentology, diagenesis, and structural history of these units to determine facies relationships and depositional environments.
- evaluate any potential structural influence on sedimentation from a local and regional perspective.

REGIONAL GEOLOGIC SETTING AND STRUCTURAL RELATIONSHIPS

The study area is situated in northeastern Illinois at the intersection of the Wisconsin and the Kankakee Arches (Pirtle 1932, Ekblaw 1938, fig. 2). The Kankakee Arch separates the Michigan Basin to the northeast from the Illinois Basin to the south. The south margin of the Kankakee Arch coincides approximately with the Sandwich Fault Zone (fig. 3). In northeastern Illinois, Ordovician and Silurian rocks dip gently to the east and northeast into the Michigan Basin (figs. 2 and 3). Gentle folds and small faults are superimposed upon this regional dip.

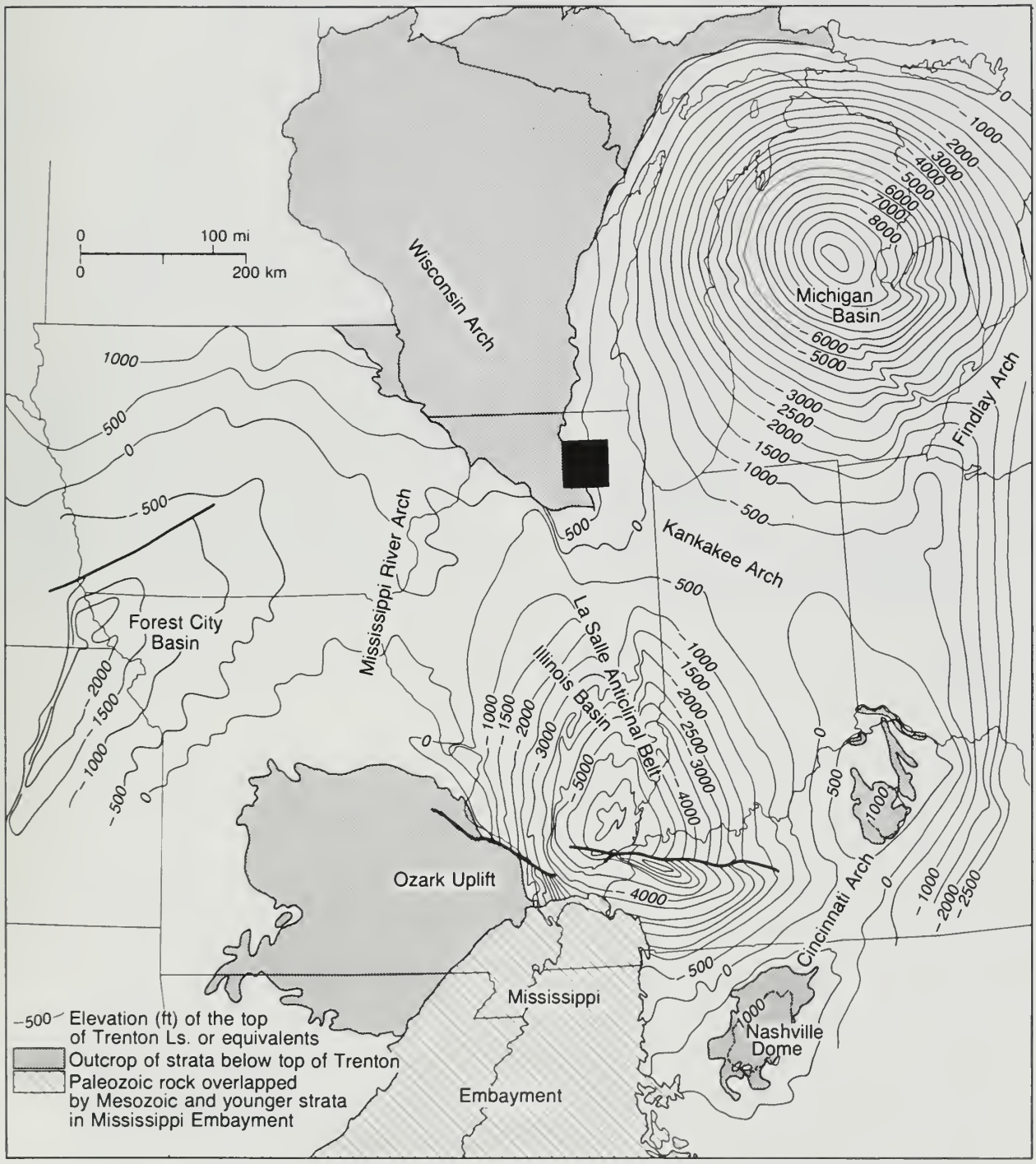

Figure 2 Major basins, arches, and domes in the north-central United States (structure contours after Cohee et al. 1962 modified from Collinson et al. 1988). Study area (box) is located in northeastern Illinois.

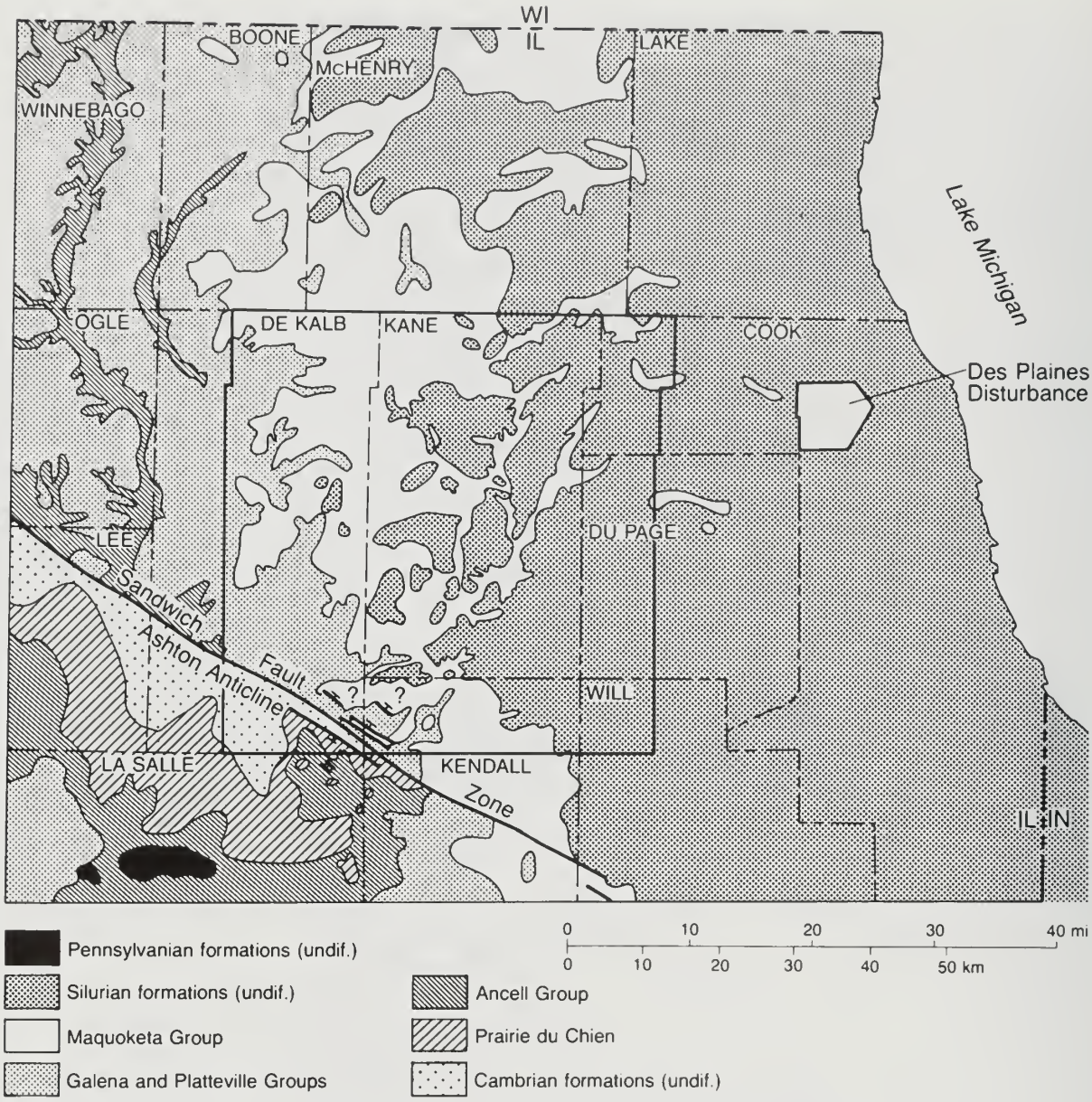

Figure 3 Geologic map of northeastern Illinois. Study area is outlined. (Modified from Willman et al. 1967, Kolata et al. 1978, Graese et al. 1988.)

In the study area, strata dip to the east and southeast approximately 10 to 15 feet per mile (0.1° to 0.2°). Late and post-Paleozoic erosion has beveled the bedrock in this area (fig. 3). Distribution of rocks at the bedrock surface partially reflects the west-to-east dip off the Wisconsin Arch (fig. 2) as well as post-Paleozoic erosion and incision of bedrock valleys (up to 400 ft [120 m]) into the bedrock. The Paleozoic rocks are largely covered by Quaternary deposits, primarily glacial and fluvial sediments of unlithified clays, silts, sands, and gravels.

The major structural feature in the area is the Sandwich Fault Zone (Kolata et al. 1978) that crosses the southwestern corner of the study area and consists of a zone of nearly vertical faults with displacements of several hundreds of feet (fig. 3). This zone consists of numerous high-angle faults that bound small grabens and horsts. The Sandwich Fault Zone is 85 miles (136 km) long and 0.5 to 2.0 miles (0.8 to 3.2 km) wide, extending from Ogle County on the northwest to Will County on the southeast. A map of this fault (Kolata and Graese 1983, fig. 5,

p. 6) shows 600 to 1,000 feet (183 to 305 m) of net throw down to the northeast on top of the Franconia Formation. Ordovician rocks are locally eroded from the upthrown blocks. At the midpoint of the main fault in southeastern De Kalb County, rocks are displaced vertically by as much as 800 feet (240 m). At its eastern end, in Will County (outside of study area), the rocks are downthrown to the south with a total displacement of about 150 feet (45 m).

The latest known faulting in the area is post-Niagaran (middle Silurian), pre-Illinoian (Pleistocene) in age (Kolata et al. 1978). Geologic relationships suggest that major movements were contemporaneous with the deformation of the La Salle Anticlinal Belt in late Paleozoic time, about 250 to 300 million years ago. However, the stratigraphic record near the fault zone is incomplete from the Silurian to the Pleistocene; and whether or not additional displacements occurred during this interval is uncertain. Pleistocene deposits as old as Illinoian glaciation cover the fault zone; however, offsets or disturbed zones that could correspond to faults in the drift have not been observed (Kolata et al. 1978).

A basement fault zone that is subparallel with the Sandwich Fault Zone and forms a graben bounded by these two faults was postulated on the basis of poor quality seismic reflection data, indirect potential field data, and seven widely spaced deep wells (McGinnis 1966, fig. 13, p. 22). McGinnis (1966) originally postulated 1,000 feet (305 m) of throw down to the southwest along the fault on top of the Precambrian. McGinnis inferred an inverse relationship between basement structures and Bouguer gravity anomalies—a relationship that was considered to be caused by variable crustal densities. A 57-mile (92-km) meandering, seismic reflection profile oriented generally north-south and northwest-southeast through Kane and Kendall Counties, with recording stations located at 1-mile intervals, was made by McGinnis between two basement wells to detail the relief on the basement. The reflection quality was generally poor, but records were ranked by McGinnis as adequate for correlation purposes.

Subsequent data indicate that the fault postulated by McGinnis has much less displacement—1,000 feet less than was originally suggested. Drill-hole data plotted on a regional basement map by Michael L. Sargent (unpublished ISGS work map and Collinson et al. 1988) does not support the fault postulated by McGinnis and shows a different contour pattern. The most noticeable differences on the map by McGinnis (1966) are a detailed Aurora Syncline and a basement fault, which contrast with a more subdued Aurora Syncline and no fault on the more regional map by Sargent.

A seismic study completed for the proposed siting of the Superconducting Super Collider provided additional information. A 3-mile-long high-resolution seismic line cuts across a narrow point of the fault zone as mapped by McGinnis (Heigold 1990). This line shows basement at about 4,000 feet (1220 m) and no evidence for major faulting there; however, several small faults were recognized in other high-resolution seismic data obtained elsewhere in the area (Heigold 1990). The lack of seismic evidence for the basement fault contradicts the inference made by McGinnis that a fault is situated in northern Kane County. The high-resolution seismic data used in the SSC study was of much better quality than that used by McGinnis (1966) and indicated some faults that were previously unknown. Due to economic constraints of the SSC project, long intersecting seismic lines, which would be more telling of the large-scale stratigraphic and structural relations of the study area, were not available. Instead, these consisted mainly of segments of lines, which were sufficiently detailed to pick up small faults but may not have been areally sufficient to show larger features such as the extent of a graben. While the disproof of a graben by recent seismic evidence (Heigold 1990) is not conclusive, the magnitude of the feature, if it exists, is significantly less than was originally hypothesized.

Unmapped small faults are likely to be present in the study area. Faults of similar magnitude have been observed in the Chicago Tunnel and Reservoir Plan (TARP) (Harza 1975, 1984,

Buschbach et al. 1982). Some elevation differences in geologic contacts were mapped as small faults by Harza Engineering (1975) in preconstruction work for TARP. During tunnel construction, however, they were observed to be minor folds rather than faults (Harza 1984, Harza with ISGS 1988). Interpretations of these small features are thus suspect until observations in tunnels, outcrops, or precisely located test borings confirm or refute their existence.

The structural picture in the study area suggests an undulating basement surface sloping east-southeast with gentle synclines and structural noses trending west-southeast to east-west. A major feature is the Aurora Syncline (Willman and Payne 1942), which if projected downward, would be slightly offset to the south from the syncline mapped by McGinnis (1966) and more limited in extent, yet more pronounced than on the map by Sargent (1988).

PAST RESEARCH

The geology of Illinois has been studied since the Worthen Surveys in the 1850s. A bibliographic index by Willman et al. (1968) details works completed before 1965. The Ordovician and Silurian rock succession in northern Illinois has been extensively studied by geologists including, most recently, Templeton and Willman (1963), Buschbach (1964), Hughes et al. (1966), Willman (1971), Willman (1973), Willman and Atherton (1975), Willman and Buschbach (1975), Willman and Kolata (1978), Kolata and Graese (1983), Mikulic et al. (1985), and Mikulic (1989). A recent compilation of Illinois Basin geology is discussed by Collinson et al. (1988).

DATA CONTROL AND METHODS OF STUDY

Study of more than 500 water-well drilling records, 30 cores, and 150 wells with cuttings sampled at 5-foot to 10-foot intervals provided the basic data used in this study. Several outcrops were also examined, but as these provided only a small vertical section of Ordovician and Silurian rocks, they were used mainly to observe general lateral continuity and sedimentary structures of the rock units. Most outcrops were located along the Fox River Valley, but some quarries (primarily Silurian) were available for examination. (Curran et al. [1988] and Mikulic [1989] provide locations of stone quarries and a subcrop map.)

Drill-hole data are relatively abundant to the top of the Galena in the study area but diminish in older, deeper rocks. The distribution of selected cores used in this study is indicated on figure 1. In addition, more than 500 well records were used in the study. Cores drilled specifically for the SSC project and identified by numbers used in the ISGS Geological Records and Samples Library are listed in table 1. Drill-hole data obtained during the SSC geologic feasibility studies are available in Kempton et al. (1987a, 1987b), Curry et al. (1988), and Vaiden et al. (1988).

Stratigraphic (facies) correlation was accomplished through a network of cross-section lines based primarily on core descriptions supplemented with geophysical logs and studies of available drill cuttings. Isopachous and structure maps were made of the major lithologic units.

Methods for studying the lithology and mineralogy of rock samples included binocular microscopic and visual examination of cores, well cuttings, and outcrop specimens. Classification of the carbonate rocks is based on Dunham (1962). Color was determined from wet samples under natural and incandescent light using the Munsell color system (Geological Society of America 1984). An estimate of carbonate content was determined using 10-percent hydrochloric acid. Carbonate rocks were then categorized as dolomite, dolomitic limestone, and limestone.

STRATIGRAPHIC RELATIONSHIPS

The following discussion of the rock units is based on previous studies and review of data obtained from the SSC study. A revised geologic map (fig. 3) and a stratigraphic column (fig. 4)

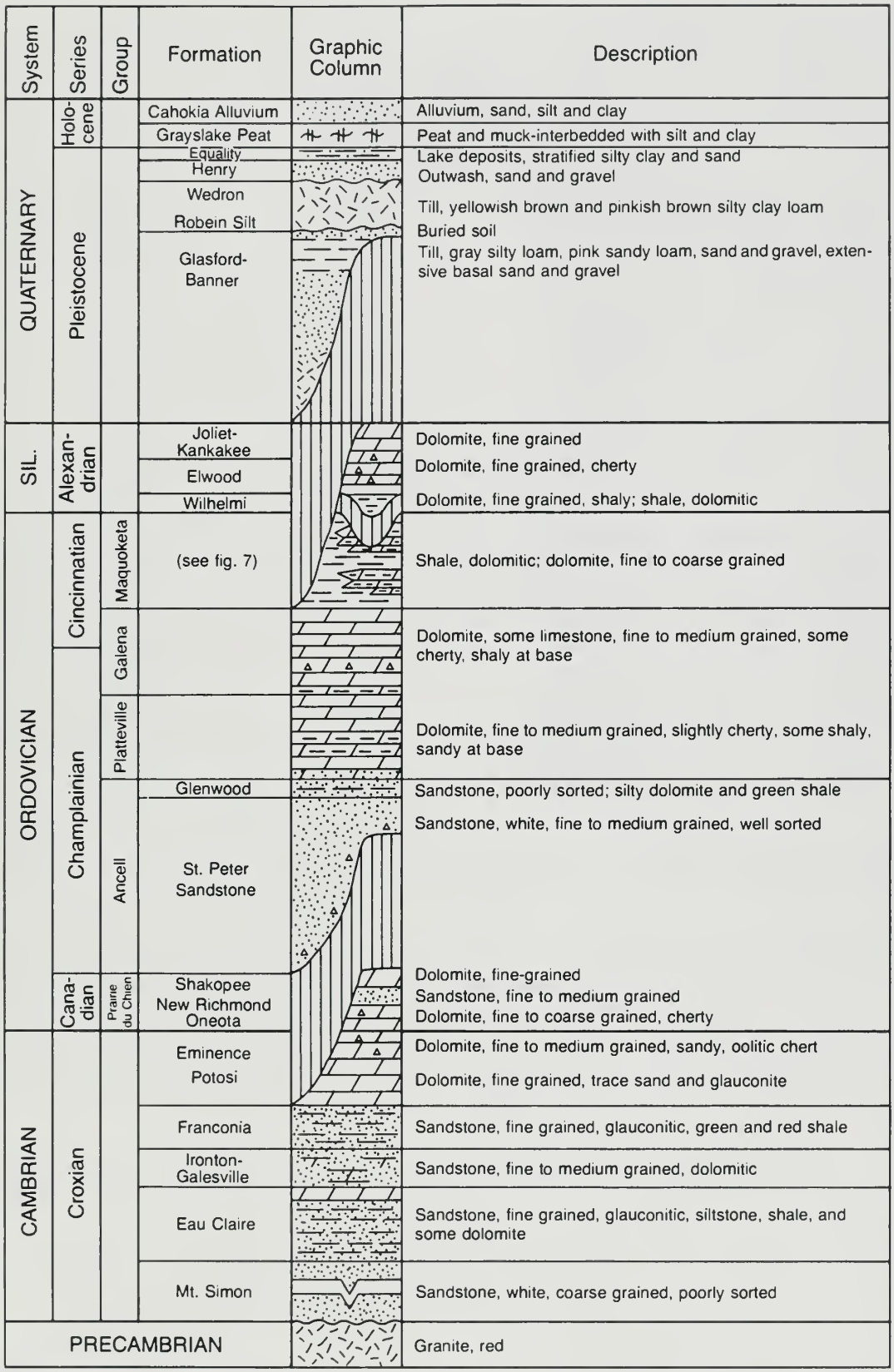

Figure 4 Generalized stratigraphic column of Paleozoic and Quaternary units in the study area northeast of the Sandwich Fault Zone (not to scale; modified from Graese et al. 1988). The entire Maquoketa section is detailed in figure 7.

Table 1 Cores used in this study

Core designation	Location	County	ISGS county no.
F-1	20, T39N-R9E	Du Page	26989
F-2	17, T40N-R9E	Du Page	26990
F-3	2, T40N-R8E	Kane	26476
F-4	11, T41N-R6E	Kane	26477
F-5	1, T39N-R5E	De Kalb	21816
F-6	23, T37N-R8E	Kendall	22022
F-7	20, T39N-R6E	Kane	26475
F-8	10, T37N-R6E	Kendall	21914
F-9	10, T41N-R5E	De Kalb	21815
F-10	25, T38N-R8E	Kane	26767
F-11	14, T38N-R5E	De Kalb	21850
F-12	10, T40N-R6E	Kane	26766
F-14	16, T40N-R4E	De Kalb	21849
F-15	30, T41N-R8E	Kane	26769
F-16	3, T37N-R7E	Kendall	21848
F-17	27, T38N-R5E	De Kalb	22059
S-18	9, T37N-R8E	Kendall	27364
S-19	16, T37N-R7E	Kendall	22103
S-20	2, T37N-R8E	Kendall	22108
S-21	7, T37N-R7E	Kendall	22114
S-22	26, T38N-R6E	Kane	27056
S-23	34, T39N-R6E	Kane	27102
S-24	22, T40N-R7E	Kane	27145
S-25	26, T39N-R6E	Kane	27183
S-26	14, T39N-R6E	Kane	27217
S-27	20, T40N-R8E	Kane	28245
S-28	5, T38N-R9E	Du Page	27575
S-29	17, T39N-R9E	Du Page	27643
S-30	36, T40N-R6E	Kane	27378

show the plan and vertical view of rocks exposed at the bedrock surface beneath the glacial drift and the vertical sequence of rocks as they occur in northeastern Illinois.

Ancell Group

The lowermost units included in this review are the sandstones and minor shales and limestones of the Ancell Group, which includes the St. Peter Sandstone and the overlying Glenwood Formation. These units were not mapped in this study, although five cores drilled for the purposes of the SSC study penetrated the upper portion of the Ancell (Kempton et al. 1987a, 1987b, Curry 1988). A structure map on the top of the Ancell, however, was constructed and is shown later in this report. The following discussion is from Buschbach (1964) and Willman and Buschbach (1975).

The St. Peter Sandstone consists of well-sorted, well-rounded, frosted, fine- to medium-grained quartz sand and local thin beds of shale and limestone. The sandstones are generally friable and weakly cemented. Some beds show low-angle crossbedding. The St. Peter ranges in thickness in northern Illinois from zero where eroded south of the Sandwich Fault Zone, to greater than 300 feet (90 m) where a relatively narrow zone of unusually thick St. Peter Sandstone passes through De Kalb, Kane, and Du Page Counties (fig. 5). The St. Peter consists of three members: the Kress Member at the base, the Tonti Sandstone Member, and the Starved Rock Sandstone Member.

The Kress Member at the base of the St. Peter consists of red sandy clay, red and green shale, and argillaceous sandstone, and coarse rubble or chert conglomerate in a clay or sand

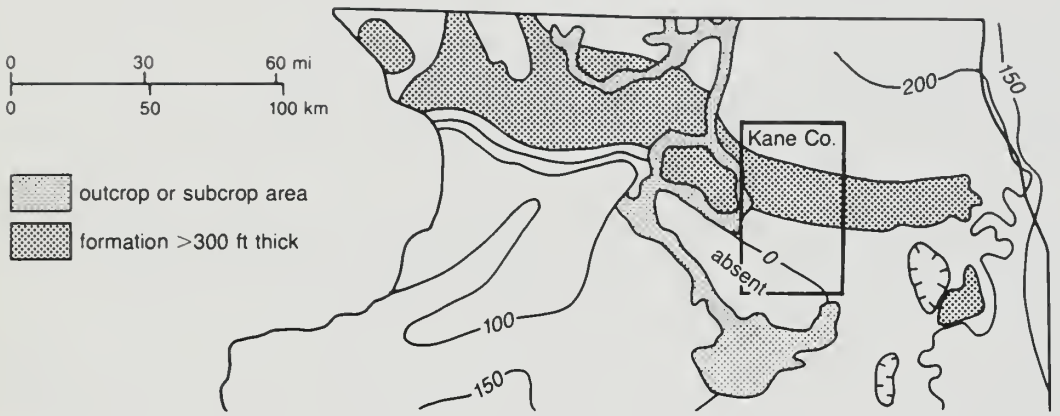

Figure 5 Isopachous map of the St. Peter Sandstone (modified from Willman and Buschbach 1975).

matrix. The Kress is not always present but has been encountered in many wells. Overlying the Kress is the Tonti Sandstone Member, a sheet sand that is commonly 100 to 200 feet thick but can be locally more than 500 feet. It consists of fine-grained, well-sorted, friable, very porous sandstone. The Starved Rock Sandstone, which lies above the Tonti in the north-central part of the state, is a medium-grained sandstone and more crossbedded. Where present, it is commonly 60 to 100 feet thick.

Overlying the St. Peter Sandstone is the Glenwood Formation which consists of poorly sorted sandstone, shaly dolomite, and green shale. The Glenwood has been subdivided into five members: the Kingdom Sandstone Member at the base of the sequence overlain by the Daysville Dolomite Member, the Loughridge Sandstone Member, the Harmony Hill Member (shale), and the Nokomis Member (sandstone).

The St. Peter Sandstone has been interpreted as a transgressive marine sheet sand deposited along the shore of a sea advancing from the south (Dapples 1955). The Starved Rock Member has been interpreted as an offshore bar separating Glenwood (lagoonal) shales, carbonates, and sands on the north from Joachim (open-marine) carbonates to the south; it is considered to be in facies relationship with both (Willman and Buschbach 1975). The St. Peter has also been interpreted as being deposited in a fluvial setting (Palmquist 1969), an aeolian setting (Berkey 1906, Mazzullo and Ehrlich 1983), a tidal setting (Amaral and Pryor 1976), and a progressive shoaling of the sea (Fraser 1976). In Minnesota, Mazzullo and Ehrlich (1987) recently evaluated the St. Peter on the basis of evidence for both windblown and water-borne sands; they suggest that the St. Peter is a tidal flat deposit similar to the tidal flats of the North Sea. Templeton and Willman (1963) and Buschbach (1964) interpreted the Kress Member to be an insoluble residuum developed on a karst surface on the underlying Prairie du Chien Group and Eminence and Potosi Formations and concentrated in local depressions by advancing seas.

The St. Peter (Ancell Group) is quarried for silica sand and is one of two major aquifers in northern Illinois, the other being the Cambrian Ironton-Galesville Sandstones (fig. 4). Thus, it is an economically important unit in the northern portion of the state.

Platteville and Galena Groups

The Platteville and Galena Groups were combined by Swann and Willman (1961) into the Ottawa Megagroup. This stratigraphic unit includes the carbonate units above the Ancell (primarily sands) and below the Maquoketa Group (primarily shales). The current North

American Code on Stratigraphic Nomenclature (1983) uses the term supergroup rather than megagroup for assemblages of groups of similar strata. The Galena and Platteville Groups have been further subdivided, mostly on the basis of surface exposures, into ten formations and 31 members (Templeton and Willman 1952, 1963, Willman and Kolata 1978). Most of these units can be recognized in surface exposures in northern Illinois but they are difficult to differentiate in cores; most are difficult to clearly differentiate in cuttings from water or oil wells.

Since these formations are very similar in lithology—all carbonates with occasional thin shaly laminae—and cannot be easily differentiated in the subsurface in northeastern Illinois, particularly in cuttings, the Galena and Platteville should more appropriately be termed formations and subdivided into members in the study area. Although these changes in nomenclature have not been adopted by the Illinois State Geological Survey, the author favors reducing the rank of the Galena and Platteville Groups to formations, and the presently used formations to members. This revision in nomenclature is only appropriate for the northeastern part of the state, where the Galena and Platteville consist of relatively pure carbonate. In northwestern Illinois, many of the units either thicken and/or become shalier and are much more readily differentiated. An example of this is the Guttenberg, which is only a few inches thick or absent in the study area and thickens to 15 to 20 feet westward (Templeton and Willman 1963, Willman and Kolata 1978). Where the Guttenberg is present in the study area, it is a distinctive unit; however, I do not believe a bed only a few inches thick should be termed a formation. Member or perhaps bed nomenclature is more appropriate for the Guttenberg in the study area. Some of the Platteville units are also much shalier to the northwest (Templeton and Willman 1963, Willman and Kolata 1978, Kolata et al. 1986). Although I believe a revision in nomenclature is necessary, the established classification will be used for this report. There is a need to evaluate the stratigraphy in a broader scale than a countywide area. To do this would require a regional assessment to the level of detail evaluated in this report (countywide level). The study of the regional stratigraphic framework is beyond the scope of this report.

In this report, the units are described to the formation level because these differentiations have been made in core descriptions (Kempton et al. 1987a, 1987b, Curry et al. 1988). On maps, however, major lithologic units have been differentiated only to the group level. Cross sections show lithologic and stratigraphic differentiation to a level adequate to show detail readable at the scale of the illustration. As most of the units have been dolomitized, fossil constituents are not readily recognizable and will not be discussed further. Biostratigraphy and paleoecology are subjects out of the realm of this paper. The Platteville and Galena typically contain a normal marine fauna of sponges, corals, bryozoans, brachiopods, pelecypods, gastropods, cephalopods, trilobites, and ostracods. Paleontologic details to species level are discussed in Templeton and Willman (1963) and Willman and Kolata (1978).

The Platteville Group, which lies below the Galena Group, is composed of light gray to brown, very fine- to medium-grained, fossiliferous, pure to argillaceous, thin- to medium-bedded dolomite separated by thin, brown to green, wavy, shaly laminae. In places the dolomite grades into calcareous dolomite and lime mudstone, as classified according to Dunham (1962). The few basal beds of the Platteville (the Chana and Hennepin Members of the Pecatonica Formation) are sandy and may contain phosphate nodules (Willman and Kolata 1978). Dark gray, mottled, shaly beds and chert nodules (less than 3 inches [8 cm]) in diameter occur locally. The Mifflin and Grand Detour Formations are more shaly than the overlying Quimbys Mill and Nachusa Formations and the underlying Pecatonica Formation. In northwestern and north-central Illinois, where the Platteville has been studied in surface exposures, the Platteville contains five formations, 15 members, and numerous beds. They are described in detail in Willman and Kolata (1970) Willman and Buschbach (1975) and Templeton and Willman (1963).

In the study area, overlying the Platteville is the Galena Group, subdivided into three formations: Guttenberg at the base, Dunleith, and Wise Lake, the youngest.

- The *Guttenberg Formation*, basal unit of the Galena, consists of pure dolomite beds separated by dark reddish brown shale laminae. In the study area the entire Guttenberg is at most 2 feet thick (0.6 m) and is often absent. The red color is caused by an abundance of the organic microfossil, *Gloeocapsamorpha prisa* (Jacobson et al. 1988).

- The *Dunleith Formation*, which underlies the Wise Lake, is a medium-grained, vuggy dolomite approximately 45 (13.5 m) feet thick. The upper 5 to 10 feet (1.5 to 3 m) is commonly vuggy; the remaining dolomite is similar but more vuggy than the overlying Wise Lake. The upper 5 to 10 feet commonly contains chert nodules and beds.

- Most of the *Wise Lake Formation* is pure, light brown, slightly vuggy to sucrosic dolomite. Generally thick bedded, the unit contains wavy, very thin shaly laminae. The upper 5 to 10 feet is commonly vuggy and locally contains oil stains and oil-filled vugs. At a few places in the Aurora area of Kane County (fig. 1), where the Dunleith and Wise Lake Formations cannot be readily differentiated from each other, the Wise Lake/Dunleith is very fine-grained lithographic limestone, locally containing beds of grainstone. A widespread, thin, clay bed—the Dygerts K-bentonite Bed (Willman and Kolata 1978), which is generally less than 2 inches (2.5 cm) thick, has been noted 80 to 100 feet (24 to 30 m) below the top of the Wise Lake.

The limestone facies of the Galena are generally very fine-grained mudstones, massive and relatively nonporous, locally containing thin coarse-grained, cemented grainstone beds. The presence of a well-preserved, normal marine fauna is suggestive of a subtidal environment with relatively low depositional energy (Willman and Kolata 1978). The coarse-grained beds (generally less than 6 inches thick) were probably produced from storm deposits (Willman and Kolata 1978) or sand waves (Delgado 1983); or they may represent small grainstone shoals (Wilson 1975). All Platteville and Galena units are light-colored, reflective of oxidizing environments. The rocks are relatively pure except for the Mifflin and Grand Detour Members (Platteville Group) and Guttenberg (Galena Group), which contain numerous shale laminae and some thin shale beds. Relatively pure to slightly shaly units in northeastern Illinois become very shaly north and northwestward into Minnesota. The source of the K-bentonites is thought to have been the Appalachian Mobile Belt, as the K-bentonites generally thicken eastward (Willman and Kolata 1978, Kolata et al. 1986). The Galena-Platteville is also used for groundwater resources in some areas and quarried for construction aggregate and agricultural limestone.

Maquoketa Group

The Maquoketa Group and its equivalent strata form the uppermost Ordovician unit in Illinois, Iowa, Indiana, Missouri, Wisconsin, and western Kentucky. The Maquoketa consists of olive-gray and greenish gray shale with some interbedded dolomite and limestone. The thickness ranges between 100 to 260 feet (30 to 78 m) where it has not been extensively eroded in northeastern Illinois (fig. 6). The Maquoketa shales represent the distal margin of an extensive clastic wedge of sediment derived from the Appalachian Mobile Belt to the east of the study area. Projected magnetic-pole positions, fossils, and rock lithologies suggest that this area was positioned approximately 10° to 15° south latitude during the Late Ordovician (Droste and Shaver 1983). Upper Ordovician sediments were deposited in northeastern Illinois in shallow marine water within an epeiric sea that covered most of North America.

The following discussion of the Maquoketa Group contains information from Kolata and Graese (1983), supplemented with information obtained during the SSC investigation. Detailed discussion of the lithologies, thicknesses, and distribution of the Maquoketa units and distribution of macrofossils for all northern Illinois may be found in Kolata and Graese (1983).

In the Chicago area east of the study area, the Maquoketa has been subdivided into the following mappable formations, listed in ascending order:

- *Scales Formation*, an olive-gray to olive-black, laminated to bioturbated, dolomitic shale locally containing biogenic carbonates and phosphorites
- *Fort Atkinson Formation*, a light olive-gray, crinoid-bryozoan-brachiopod, bioclastic dolomite packstone and grainstone
- *Brainard Formation*, a greenish gray, silty, fossiliferous, dolomitic, burrowed shale containing thin interbeds of dolomite ranging from mudstones to grainstones
- *Neda Formation*, a red, green, orange, yellow, purple silty shale containing flattened iron-oxide spheroids (Kolata and Graese 1983).

Figure 7 shows the cross-sectional, stratigraphic relationships from the study area eastward, which indicates that the middle carbonate unit in the study area can be correlated to the Fort Atkinson in the Chicago region. The Neda and locally the Brainard lithologies are often absent, particularly in the southern part of the Kane County study area. This study consists of a

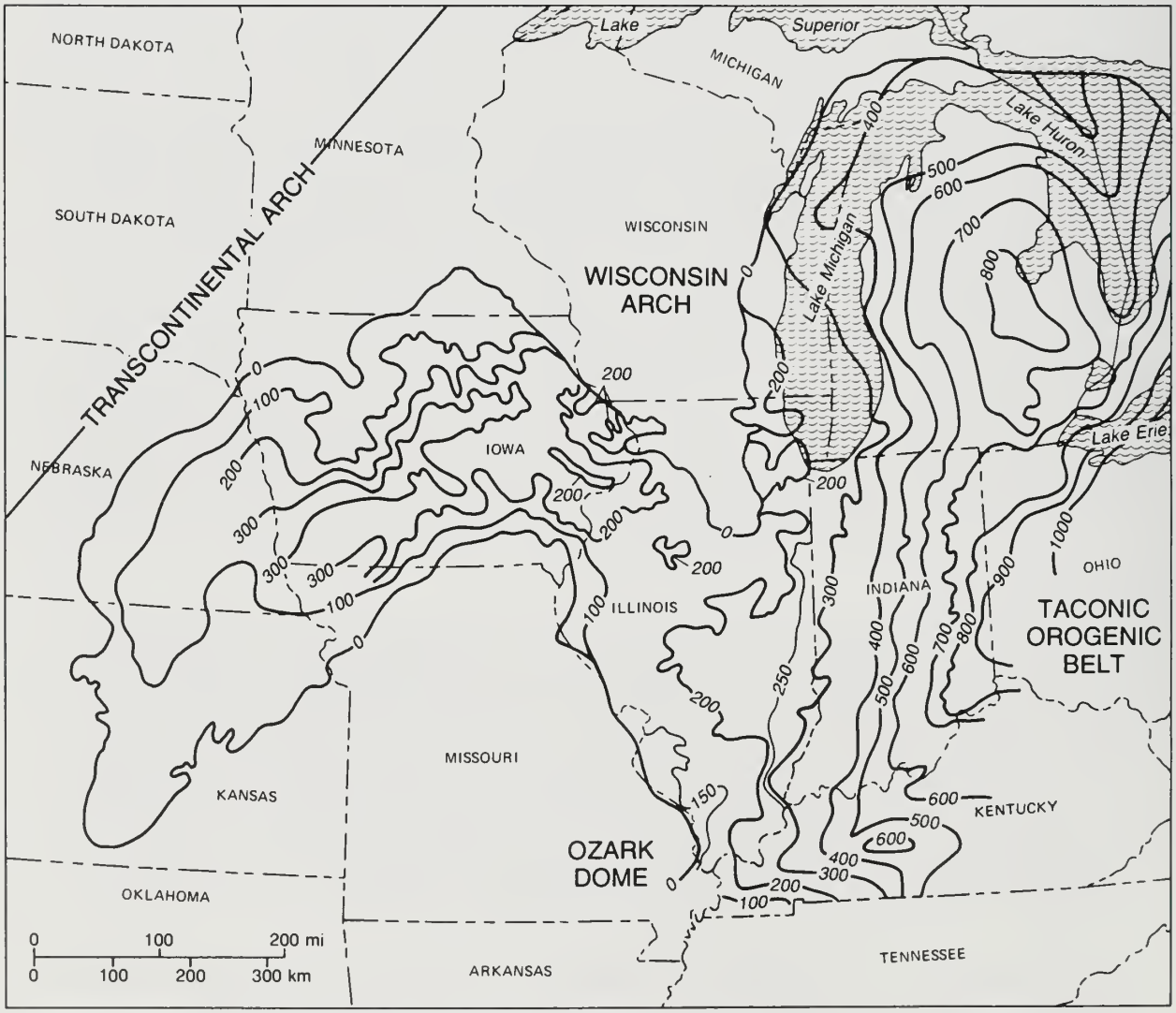

Figure 6 Regional thickness of the Maquoketa and equivalent strata in the Midcontinent (modified from Kolata and Graese 1983, Whitaker 1988).

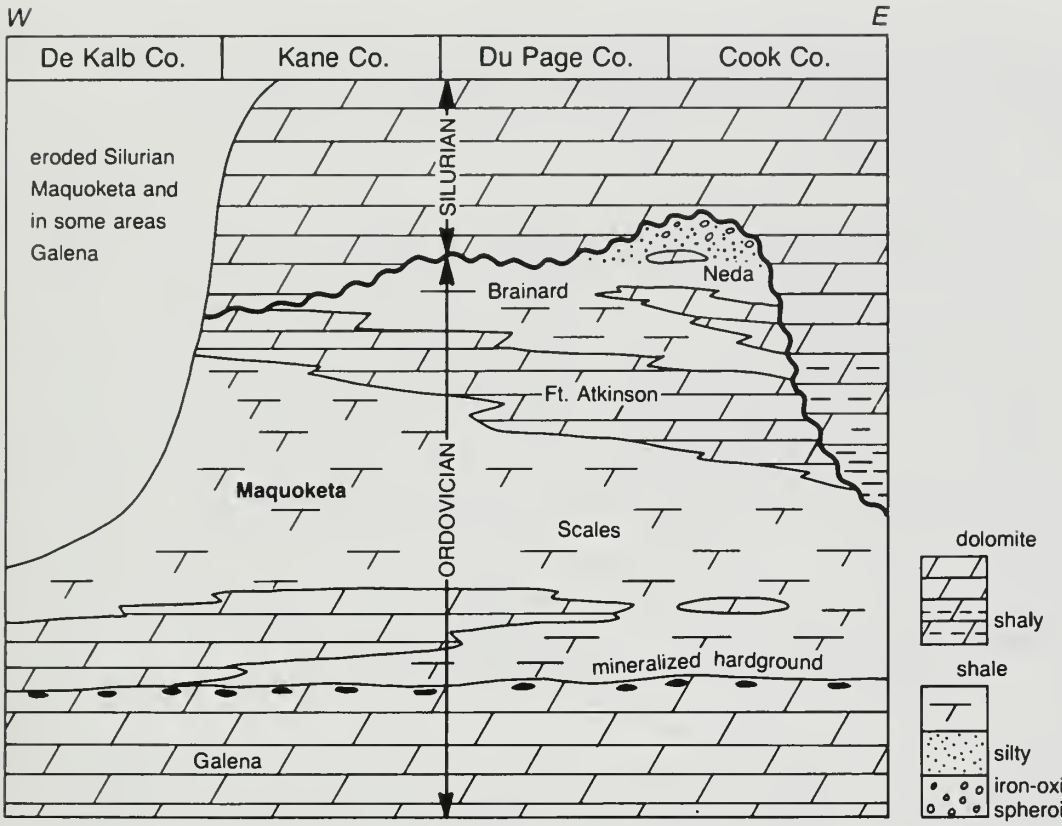

Figure 7 Generalized stratigraphic relations of the Maquoketa Group in northeastern Illinois (modified from Kolata and Graese 1983).

detailed coverage of Kane and portions of the surrounding Cook, Du Page, Will, Kendall, and De Kalb Counties where anomalously thick carbonates were noted and atypical facies relationships were previously recognized by Kolata and Graese (1983).

The shales in the Maquoketa in the study area range from olive-gray, greenish gray to reddish or purple, reflecting various degrees of oxidation; they are silty and dolomitic, ranging from soft to moderately hard. The greenish gray shales typical of the Brainard are often very soft, particularly in the upper 5 to 10 feet (1.5 to 3 m) of the Maquoketa. They may be burrowed, laminated, or massive. The dolomites and limestones vary from shaly mudstones to grainstones. The coarser-grained units are wavy bedded and may be burrowed, laminated, cross-laminated to crossbedded grainstones. There are traces of pyrite consisting mainly of tiny crystals disseminated throughout the shales, but are most common in the laminated olive-gray shales at the base of the unit. They are usually a few millimeters in diameter, but in places, pyrite also occurs as vug fillings up to ½ inch (1 cm) in diameter. Rare occurrences of pyrite are altered to sulfates. Some of the cored holes show shales that exhibit several soft sediment deformation features (Kempton et al. 1987a, 1987b, Curry et al. 1988).

In the study area, Maquoketa lithologies vary over short distances, unlike those of the underlying Galena and overlying Silurian bounding units, which are more uniform and laterally persistent. As a consequence of its more complex facies relationships and thinness, the Maquoketa should be reduced in rank from a group to a formation subdivided into members in the study area (North American Commission on Stratigraphic Nomenclature 1983). These changes in nomenclature have not been adopted by the Illinois State Geological Survey, but the author favors ranking the Maquoketa as a formation, and the Scales, Fort Atkinson, Brainard, and Neda as members in the study area. The Scales also shows a considerable carbonate component, in contrast to the Scales eastward toward Chicago, which consists

predominantly of dark brown shale. The Brainard and Neda are partially represented in the northern and northeastern part of the study area. However, for the present study, the established classification will be used to minimize confusion until the stratigraphy can be evaluated on a regional scale.

Silurian Formations

The uppermost (youngest) bedrock formations underlying the Quaternary System in the central and eastern part of the study area (fig. 3) are dolomites and limestones of Silurian age. These units should also be appropriately called members within a more inclusive carbonate unit comprising the Wilhelmi, Elwood, Kankakee, and Joliet Formations, as they are named at present. The Wilhelmi, Elwood, and Kankakee have in the past (Willman 1973) been grouped under the term Alexandrian—a chronostratigraphic term—not an appropriate lithostratigraphic unit under the North American Commission on Stratigraphic Nomenclature (1983). However, because the lower Silurian units were not entirely evaluated, and there is only a thin cover of Silurian in most of the study area, these units have been designated as formations for this report.

- The *Wilhelmi Formation*, the oldest Silurian rocks, is generally present only where the top of the Maquoketa is deeply eroded (Willman 1973, Mikulic et al. 1985). The lower part of the Wilhelmi is a medium to dark gray, very shaly dolomite and dolomitic shale (Schweizer Member). The overlying Birds Member consists of slightly cherty, medium to dark gray shaly dolomite. The Wilhelmi is represented in boreholes S-27 (19.5 ft, 5.9 m) and S-30 (14.2 ft, 4.3 m) (fig. 1).

- The *Elwood Formation* consists of light gray, fine-grained dolomite with layers and nodules of white chert several inches thick. The Elwood is typically 20 to 30 feet (6 to 10 m) thick where it has not been eroded; it grades upward into the Kankakee.

- The noncherty, relatively pure dolomite of the *Kankakee Formation* is 20 to 50 feet (6 to 15 m) thick where not eroded. The Kankakee consists mainly of greenish to pinkish gray, fine- to medium-grained, slightly cherty glauconitic dolomite in beds 2 to 4 inches thick and separated by thin greenish gray shale partings. The Kankakee has been subdivided into four members that have not been differentiated here (Willman 1973). The Kankakee is typically 20 to 50 feet (6 to 15 m) where not eroded. Within most of the study area, the Kankakee is missing or partly eroded except at test hole F-1 (fig. 1) and along the eastern margin of the study area, where it is overlain by the Joliet.

- The *Joliet Formation* consists of 40 to 80 feet (where not eroded) of dolomite that is shaly and silty at the base and progressively more pure toward the top. It is also subdivided into three members: Brandon Bridge, Markgraf, and Romeo, which have not been differentiated here (Willman 1973). The Silurian thickens from an erosional feather edge in Kane and Kendall Counties to more than 500 feet (152 m) in Chicago, where the uppermost Racine Formation (not present in the study area) consists of 300 feet (91.4 m) of the Silurian section. Additional discussion of Silurian carbonates in the Chicago region appears in Willman (1971), Willman (1973), Willman and Atherton (1975), Mikulic et al. (1985), and Mikulic (1989).

DISCUSSION OF LITHOFACIES, DEPOSITIONAL ENVIRONMENTS, AND STRUCTURAL HISTORY

Focus in this section is primarily on variations in the Maquoketa facies. Immediately overlying and underlying carbonates are considered here to put the Ordovician and Silurian rocks in context and to detail the depositional and structural history. Diagenesis of carbonates is discussed briefly, but as the carbonates were not studied microscopically or isotopically, additional work would be required to analyze the diagenetic history more thoroughly. The maps below are discussed from oldest to youngest as the rocks were deposited.

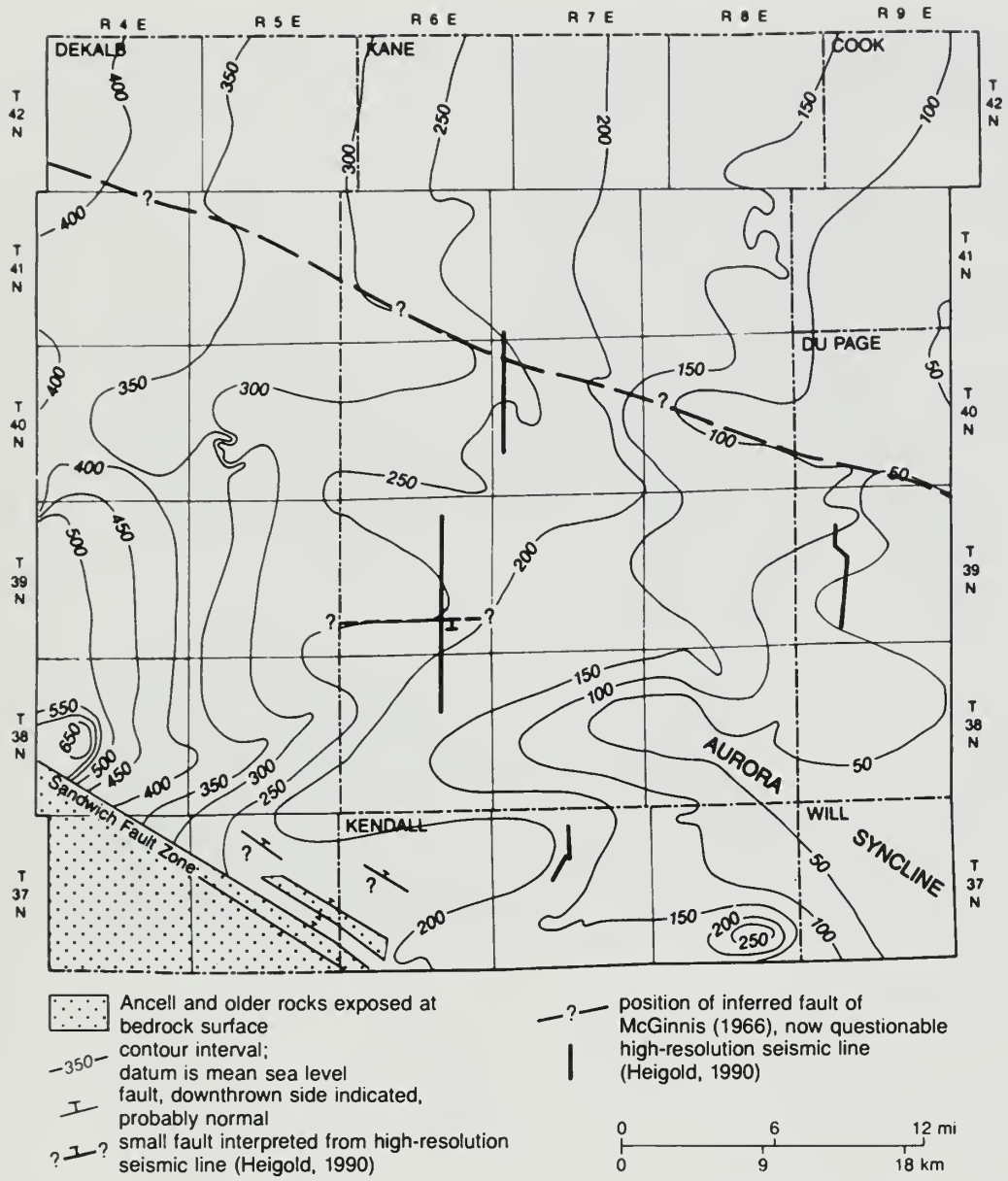

Figure 8 Structure contours on top of the Ancell Group (modified from Graese et al. 1988). Map is inferred on the basis of 326 datum points.

Information presented here and regional geologic considerations form the basis for interpreting Ordovician strata in the study area as a major transgressive sequence, including the Tippecanoe I Sequence of Sloss (1963, 1988). The transgressive sequence is bounded at the base by the sub-Tippecanoe unconformity (base of Ancell) and above by the pre-Silurian unconformity. The Tippecanoe II sequence ranges from Early Silurian to Early Devonian (not represented in this area.) The unconformities, where present, indicate regression, erosion, or nondeposition. Sloss (1988) discusses the entire geologic sequence; in the same volume, Collinson et al. discuss the history of the Illinois Basin, and Fisher et al. discuss the Michigan Basin. The study area is located, on the basis of these papers, at the western edge of the Michigan Basin.

Ancell Group

The structure map constructed on top of the Ancell Group (fig. 8) shows that the elevation is the lowest along the Aurora Syncline (Willman and Payne 1942). West, north, and south of the

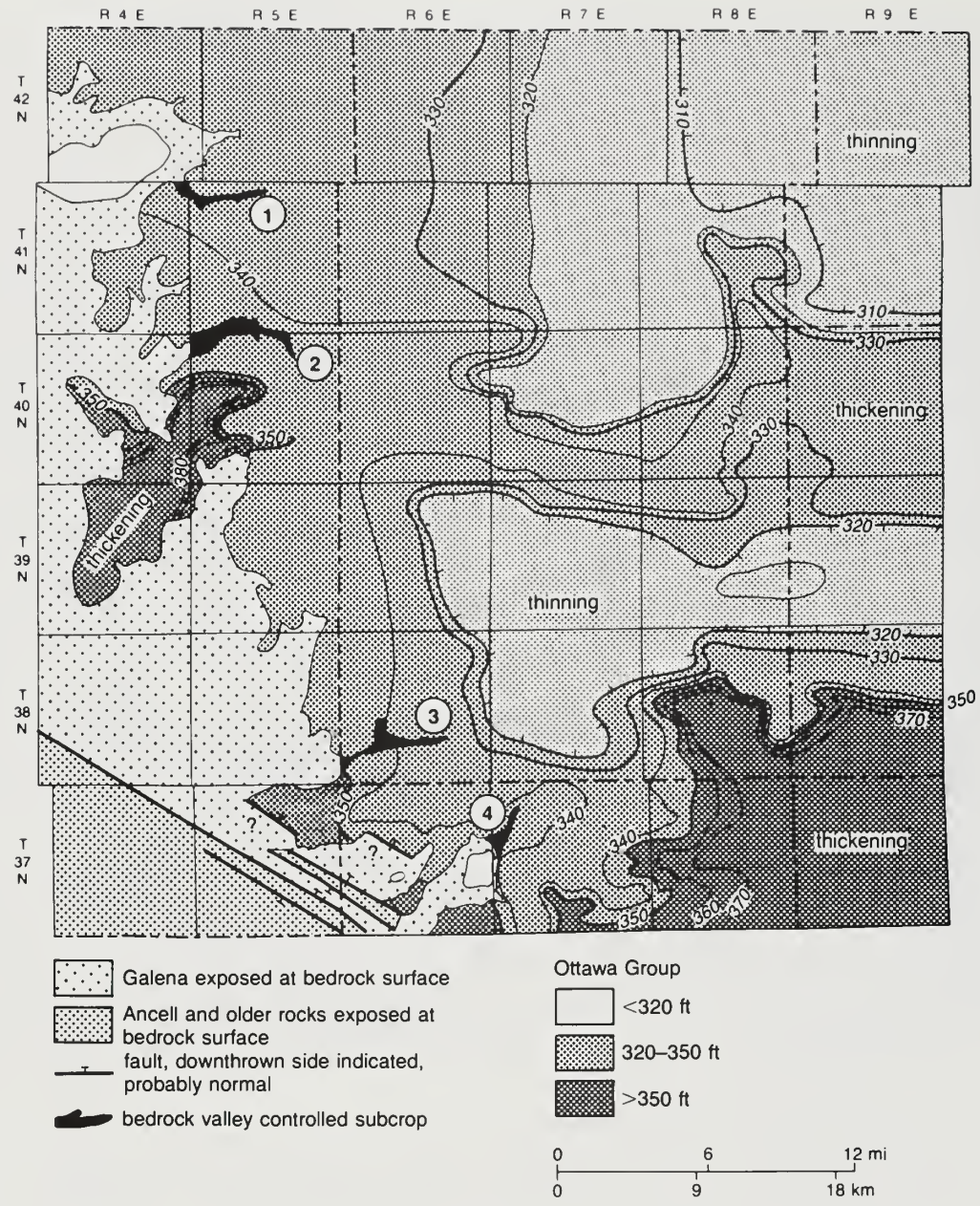

Figure 9 Galena-Platteville combined isopachous map (modified from Graese et al. 1988).

syncline the rocks generally rise in elevation from less than 50 feet to greater than 400 feet above mean sea level. The elevation changes shown on the maps may represent folds or small faults. Some of the straighter, elongate segments of contour lines may be faulted. A few faults have been identified by high-resolution seismic techniques (Heigold 1990), but no one-to-one correlation between faults and straight line contours has yet been demonstrated, except where tested by seismic methods. The position of the fault inferred by McGinnis (1966) and previously discussed is shown for reference purposes.

Platteville and Galena Groups

An isopachous map of the Platteville and Galena combined (fig. 9) shows that the interval is thickest—greater than 350 feet—in the southeastern corner of the map area along the Aurora Syncline. The remaining trends are more east-west and show thin areas to the northeast and

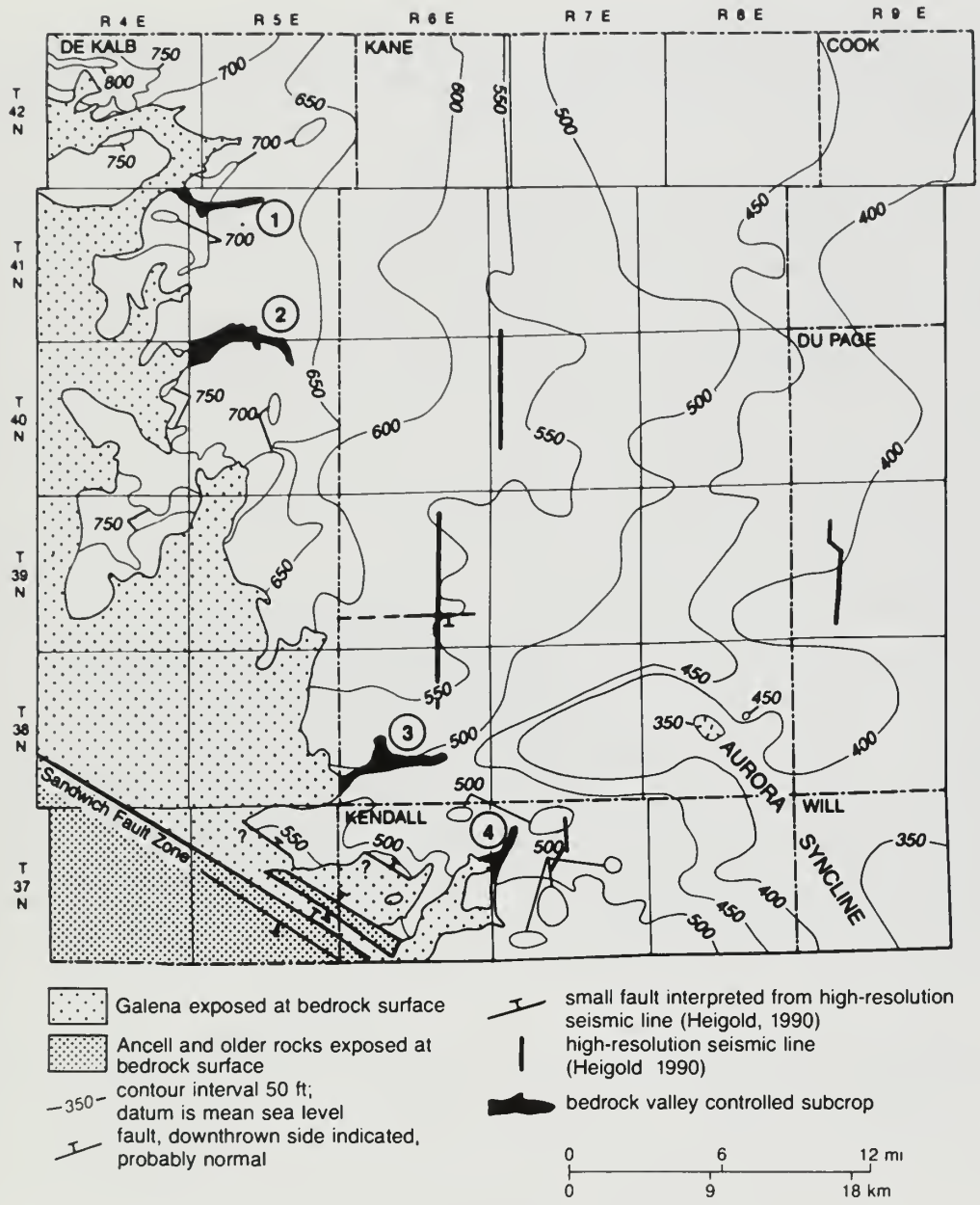

Figure 10 Structure contours on top of the Galena Group (modified from Graese et al. 1988). Map is inferred on the basis of 500 datum points.

central portions of the map. Thickened sections (greater than 320 feet [98 m]) occur to the northwest and west. The Aurora Syncline may reflect continued subsidence and accumulation of subtidal carbonates in that region. In that context, thinned areas may reflect slightly elevated areas relative to subsided areas (thickened areas).

The structure on the top of the Galena (fig. 10) also shows the Aurora Syncline. Elevation increases northwest, north, and southwest of the Aurora Syncline from 350 feet in the syncline to greater than 800 feet (245 m) in the northwest corner of the map.

The map of the percentage of limestone in the Wise Lake Formation of the Galena Group (fig. 11) shows a general concentration of limestone along the Aurora Syncline. The structure on top

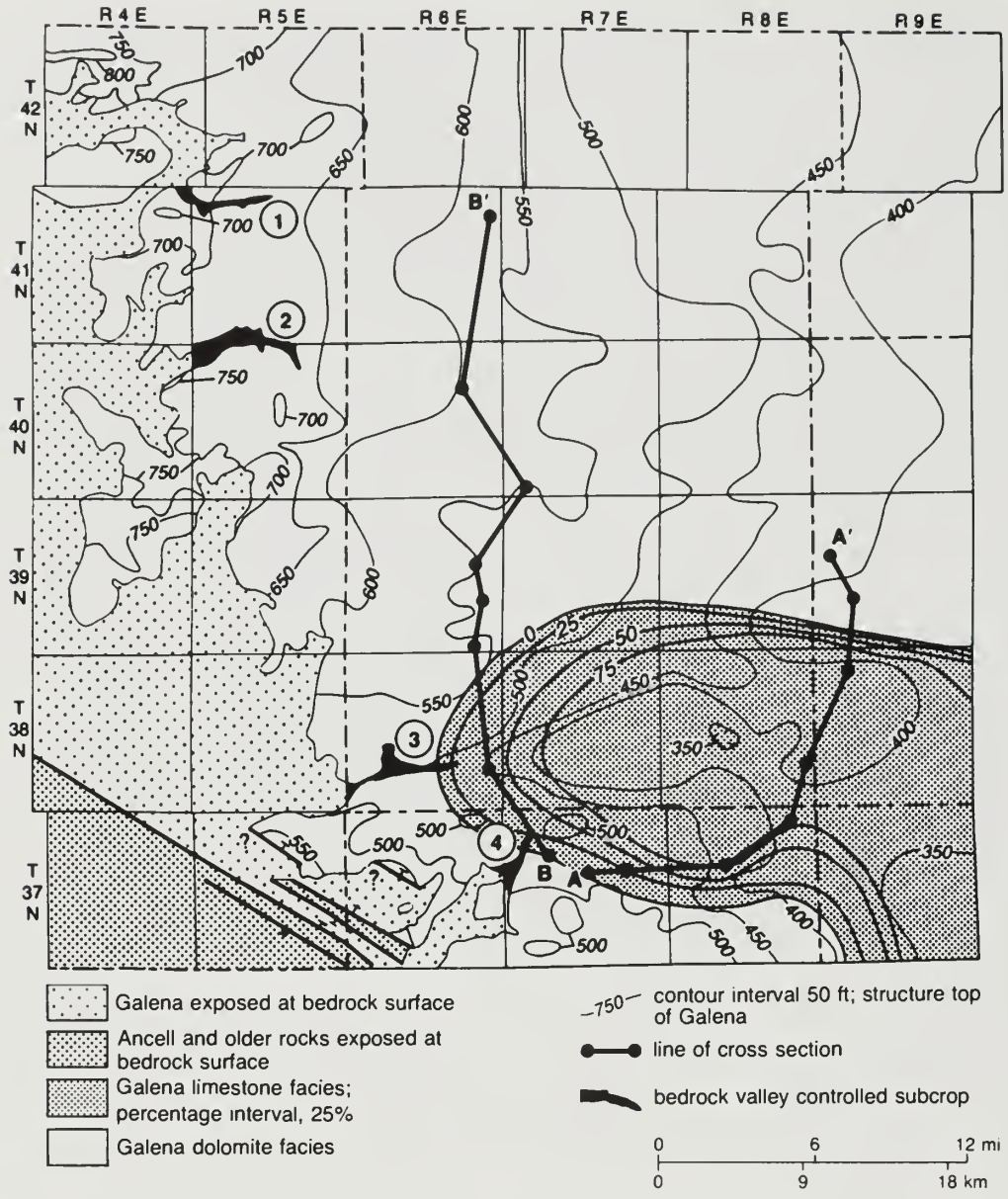

Figure 11 Percentage limestone distribution of the Wise Lake Formation. Percentage is inferred on the basis of 30 datum points.

of the Galena in figure 11 has been superimposed to show this relationship. The cross section (A-A′) in figure 12 cuts across the center of the syncline and shows the facies relationships. The cross section (B-B′) in figure 13 cuts across the end of the syncline (borehole S-22) along the southern part of the section.

The shale and carbonate Ordovician and Silurian lithofacies in the midcontinent and described in this paper are generally reflective of shoaling-upward sequences in shallow marine water. Eustatic sea-level changes have been suggested as the possible mechanism for the cyclicity (Witzke and Kolata 1988, fig. 7, p. 67). The Platteville and Galena represent sedimentation on a shallow carbonate shelf. Wilson (1975) describes a typical carbonate shelf as consisting of upward-shoaling sequences (regressive cycles) that result from seaward progradation of carbonates that are topped by sand shoals over a broad, gently sloping shelf. The lithofacies of

the Platteville and Galena are primarily lime mudstone to wackestone, suggestive of a low depositional energy, subtidal environment capped by occasional coarse-grained packstone to grainstone beds (intertidal). Most of the Galena and Platteville rocks have been dolomitized, thereby obscuring some of the original depositional texture.

Dolomitization is pervasive within the study area except in the Aurora Syncline. This dolomitization may reflect a Dorag model of dolomitization, implying that the syncline continuously subsided during deposition within a freshwater-seawater interface (Badiozamani 1973, Land 1983). In this model, mixing-zone environments (mixing of saline and fresh [meteoric] waters) migrate through the ground during marine regressions, as freshwater phreatic environments move seaward toward the marine phreatic zones. Paleostructural highs would coincide with the areas of dolomitization if the mixing-zone model represented the process responsible for the dolomitization. Badiozamani (1973) suggested that dolomitization of the Platteville and Galena occurred within mixing-zone environments associated with the periodic emergence along the western flank of the Wisconsin Arch northwest of the study area (fig. 2). The configurations of dolomitization that he mapped trended approximately north-south, with the dolomite grading to limestone from east to west off the western flank of the arch. He inferred that this configuration also extended eastward off the eastern flank of the arch, although his data did not extend into northeastern Illinois. This configuration does not appear to reach into the Kane County study area, except along the Aurora Syncline; but east of the study area, limestones are present in the Michigan Basin (Gregg 1982, Delgato 1983, Fisher et al. 1988). Locally, the east-west structural trends in the study area are opposite to the overall, north-south regional trends.

Another possible explanation of dolomitization is that the studied units were exposed subaerially after deposition. If the dolomitization of the Galena and Platteville was caused by subaerial exposure, the uppermost Wise Lake Formation would be dolomitized all across the area and exhibit abundant dissolution features such as caves or karst features at the Galena-Maquoketa contact. However, some caves along joints have been observed in Illinois, Iowa, and Minnesota in the Galena (Bretz 1938, 1939, 1940). Caves are distributed throughout outcrop areas in Illinois but concentrated in the limestones of southern and southwestern Illinois; a few caves are known within the glaciated portions.

The pitted, slightly fractured planar, upper surface of the Galena probably was formed by submarine solution. Fara and Keith (1984) and Keith (1985) proposed that the upper Trenton surface in Indiana represents a submarine corrosion surface. A hard ground or corrosion surface characterized by a pitted surface with small amounts of relief and bands of pyrite and phosphate mineralization occurs at the top of the Galena (Delgado 1983, Kolata and Graese 1982). A hard ground results from short interruptions in sedimentation, whereas an unconformity encompasses a long period of erosion or nondeposition.

The explanation proposed by McHarque and Price (1982) for the dolomitization of carbonates is that the magnesium and iron necessary for forming dolomite were derived from the conversion of smectite to illite in associated shales. Fluids expelled from the sediments as the overlying Maquoketa compacted might have moved laterally, explaining part of the dolomitization as forming as a consequence of the introduced magnesium along the margins of the Wisconsinan Arch. Under this model, a cap dolomite would be expected to form at the top of the Galena Group. No such cap dolomite is present (fig. 12) except along the center of the Aurora Syncline. Eastward into the Michigan Basin, however, the Trenton is primarily a limestone with a defined cap dolomite (Fisher et al. 1988).

Geologic mapping suggests the Dorag model of dolomitization is most applicable to the Galena in Kane and surrounding counties. The lack of dolomitization within a structural low in the Aurora Syncline implies the syncline was actively downwarped during Galena sedimentation.

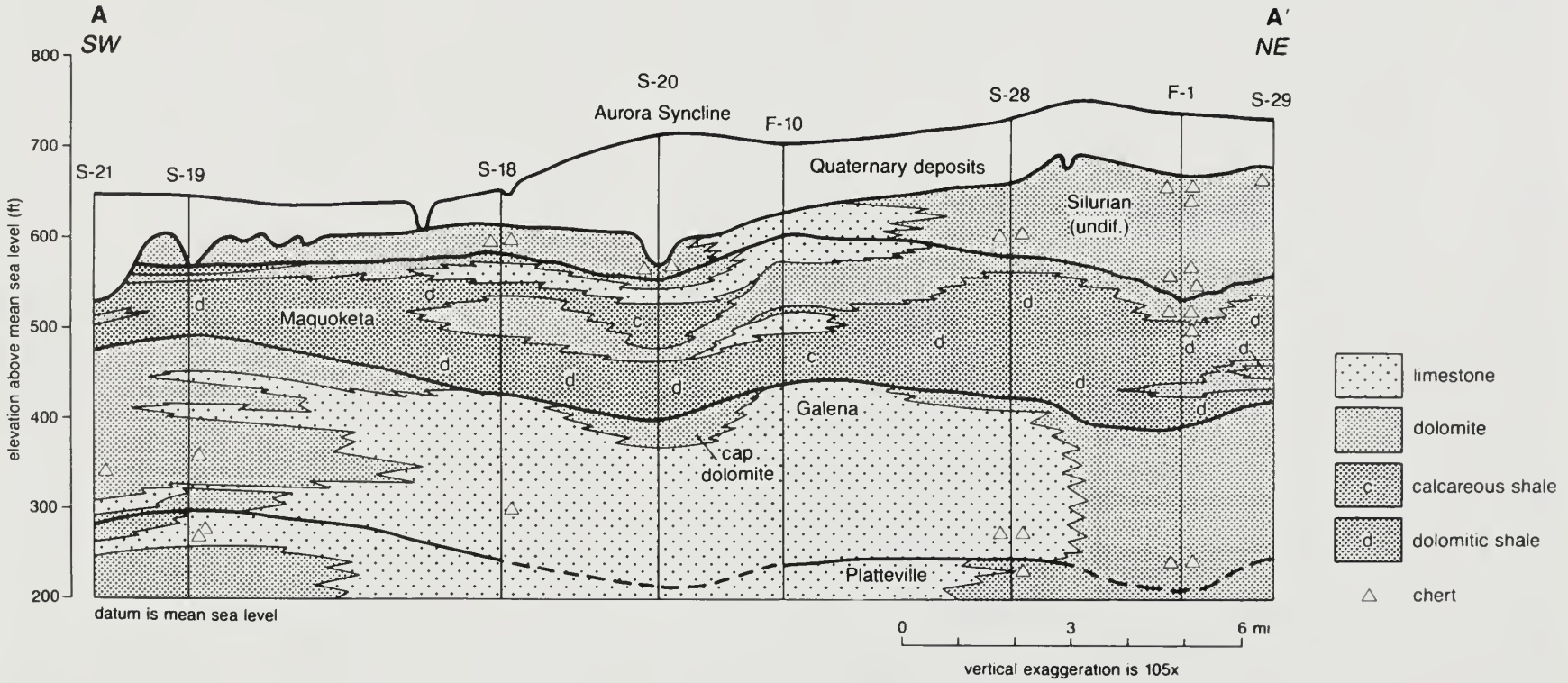

Figure 12 Cross section through the Aurora Syncline depicts diminished limestone upward. Line of cross section is shown in figure 11.

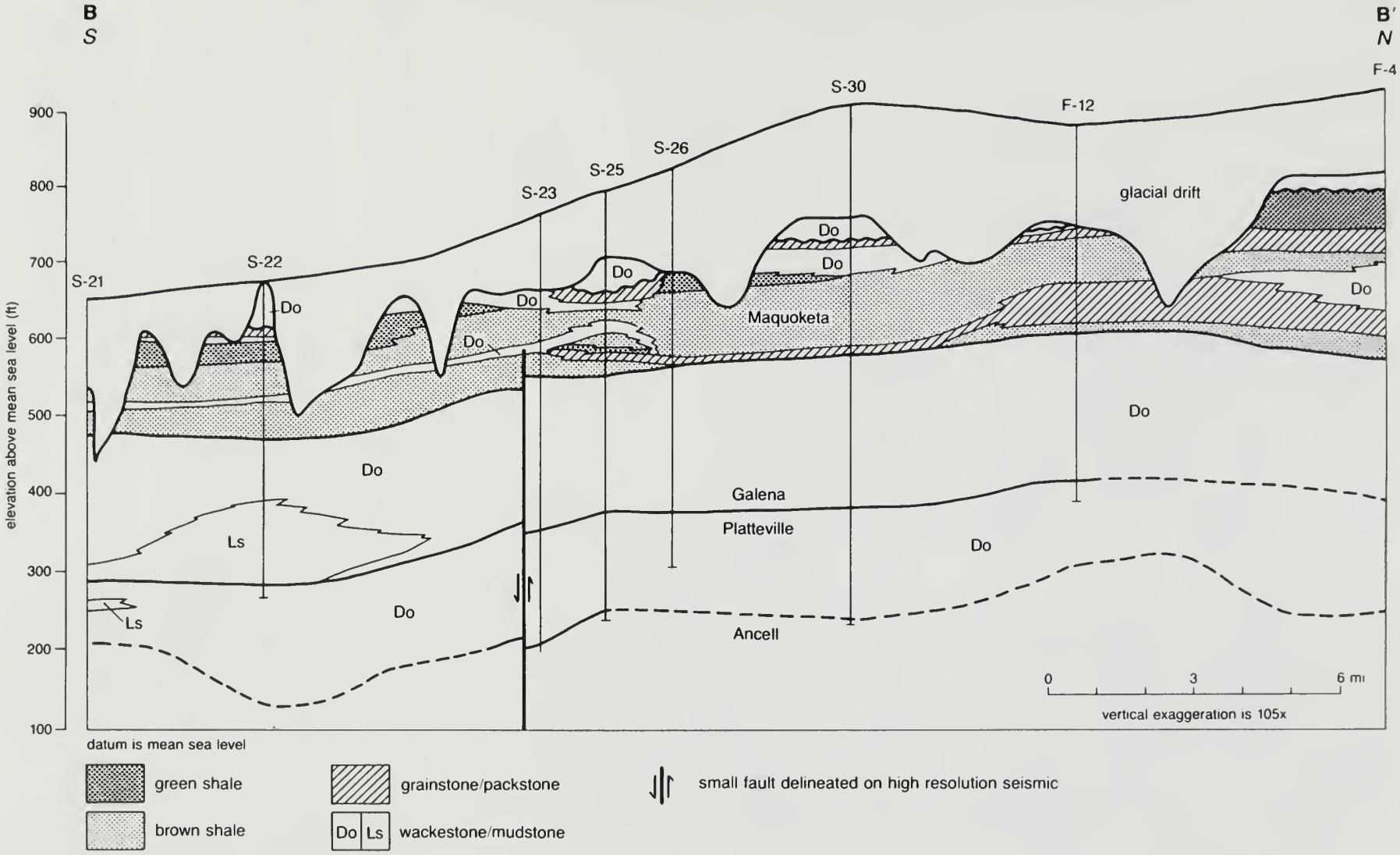

Figure 13 Cross section along the western margin of the study area shows position of a small fault known from high-resolution seismic and facies relationships. (Other small faults with vertical displacements of 50 feet (15 m) or less may be present, but they cannot be accurately mapped with present data control.) Line of cross section is shown on figure 11.

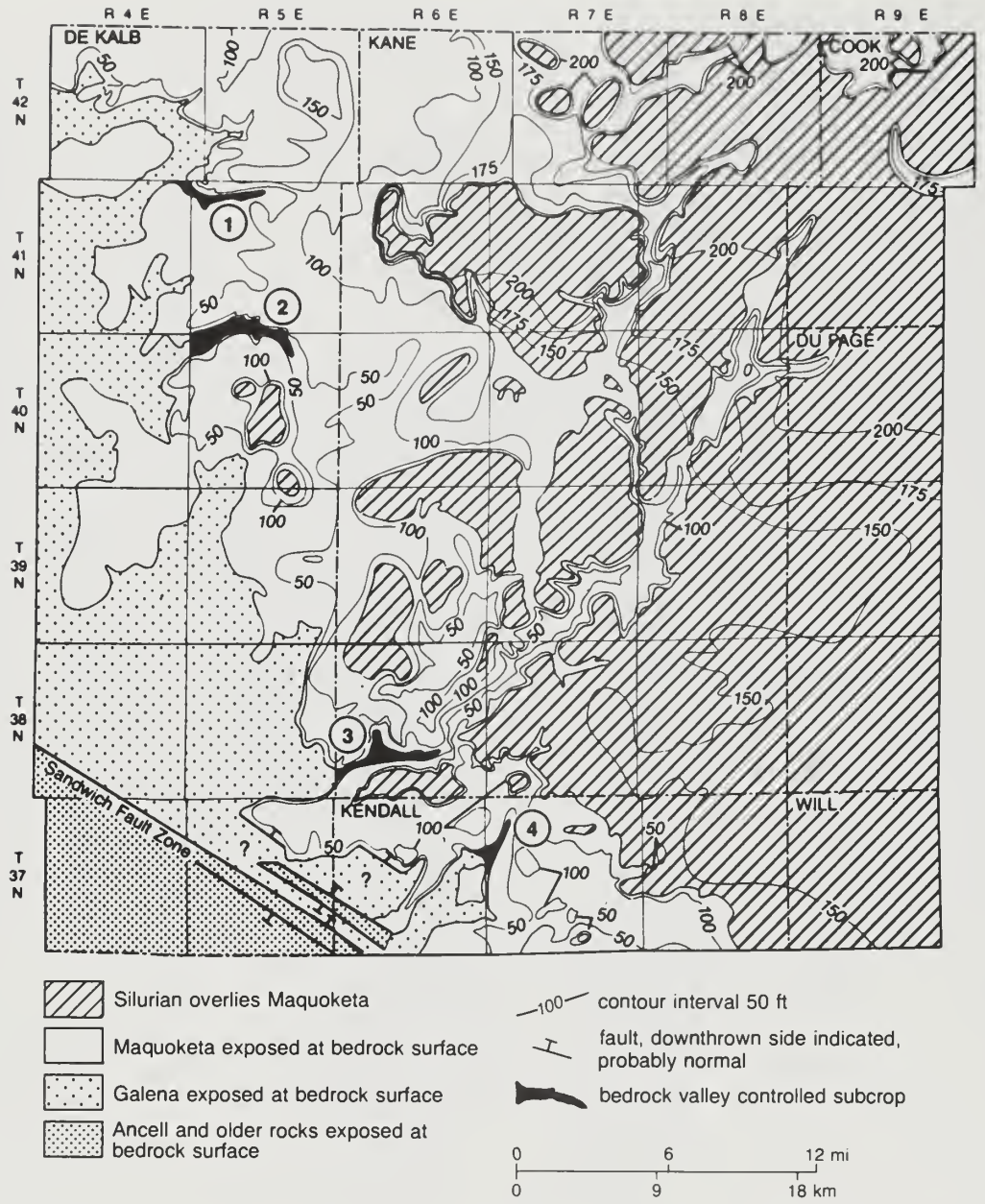

Figure 14 Maquoketa isopachous map (modified from Graese et al. 1988). Map is inferred on the basis of 400 datum points.

Maquoketa Group

In areas where the Maquoketa was not eroded prior to the Silurian or Quaternary, it varies from less than 100 feet in the southeastern part of the map to more than 200 feet in the northern and northeastern parts (fig. 14). In areas where the complete Maquoketa section is present (slashed pattern, fig. 14), a slight thickening to 150 feet occurs along the Aurora Syncline in T38N, T39N, and R8-9E; thinning occurs in the northern part of T39N. The Maquoketa abruptly thickens northward from less than 150 feet in parts of T39N to more than 200 feet in T40N.

A map of the packstone-grainstone component of the Maquoketa shows that the greatest percentage occurs in the northern and northwestern portion of the map (fig. 15). The greatest concentration (greater than 60 percent) occurs in T40N, R6E, and adjacent townships to the east, west, and north (fig. 15) where erosion has removed a significant amount of the shaly

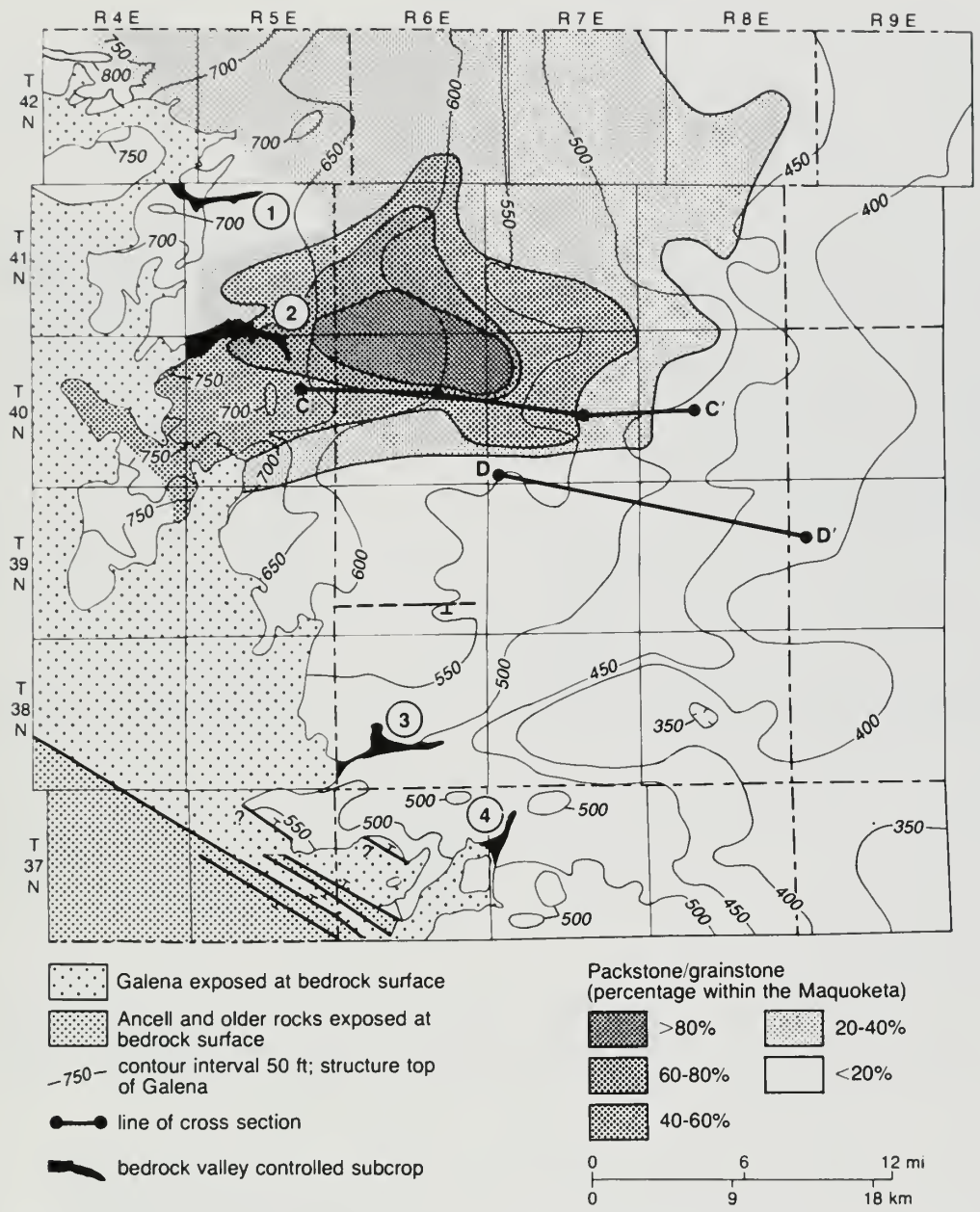

Figure 15 Distribution of packstone-grainstone within the Maquoketa Group. Map is inferred on the basis of 127 datum points.

units that overlie a basal grainstone/packstone. The Maquoketa is thicker than average in the part of the area with the highest percentage of packstone/grainstone. Some thickening may be due to the fact that the carbonates do not compact as readily as do shales; however, the thickened carbonate section here represents a facies change. The carbonates probably represent deposition of intertidal carbonate shoals at wavebase along a paleohigh, which remained at wavebase while the southern and eastern parts of the study area subsided below wavebase into deeper water. Carbonate packstone-grainstone was produced more rapidly on the shoals than in the areas of deeper water.

Examples of Maquoketa shoaling sequences developed on a paleotopographic high in shallow water (borehole F-12) are compared to a slightly lower paleotopographic area in deeper water (borehole S-30), as shown in figure 16.

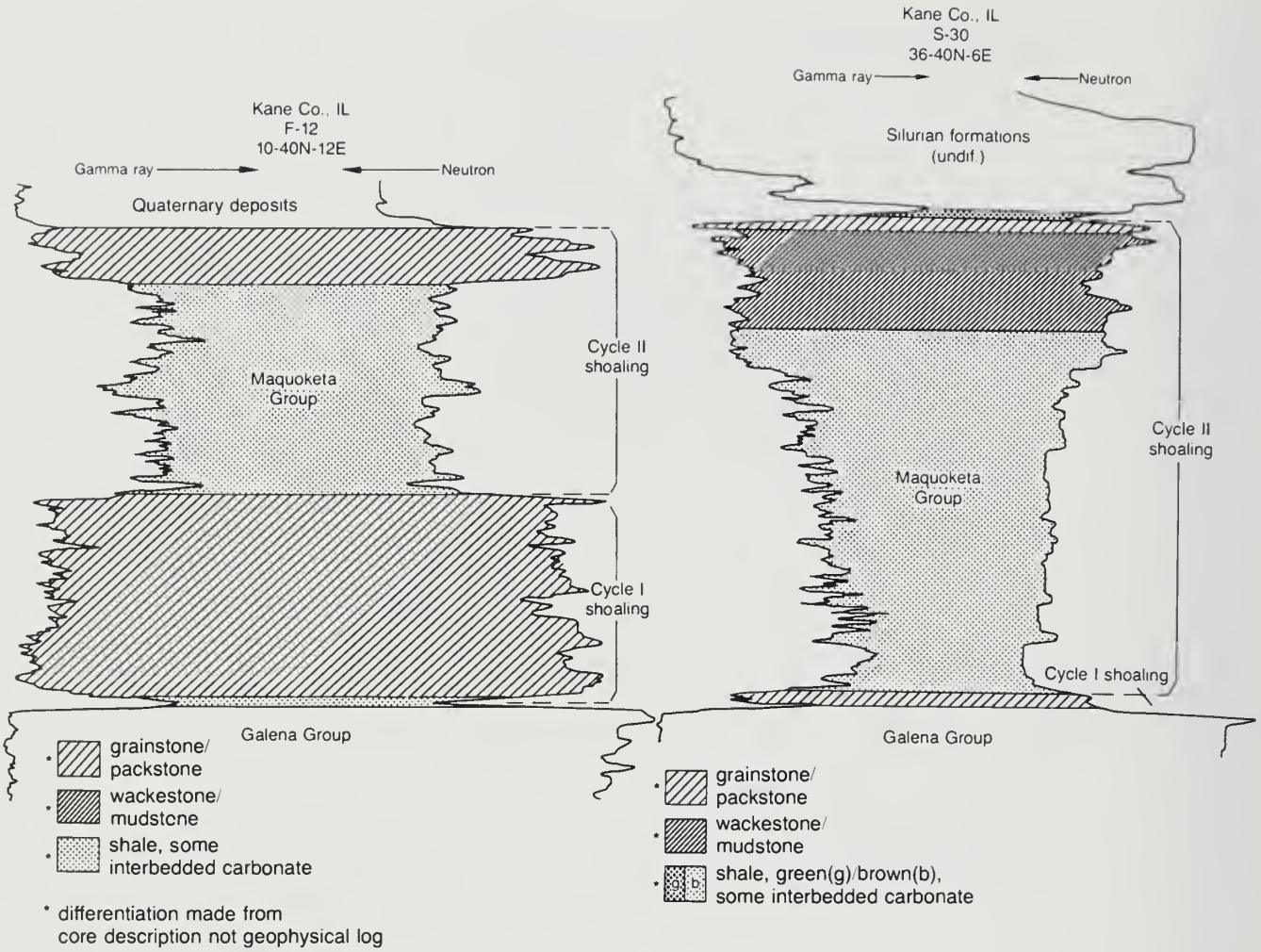

Figure 16 Typical geophysical logs depict shoaling cycles in the Maquoketa. Log (left) along the northern part of the study area shows thickened grainstone-packstone facies along a paleotopographic high. Log (right) shows thinned grainstone-packstone with concommitant increase in shale and mudstone-wackestone facies along a paleotopographic low in the southern part of the study area.

The logs show a greater percentage of carbonate in F-12 as compared to S-30. Also, grainstones and packstones predominate in F-12, whereas the carbonate constituents are predominantly mudstone-wackestone in S-30. Dolomite units thicken northward on the paleotopographic high (northern area) and are more typically grainstone-packstone than shaly dolomite mudstone-wackestone or limestone—units typical of the paleotopographic low. The cross section in figure 13 shows these relationships. Cross sections 17 (C-C′) and 18 (D-D′) were constructed along the thickest portion of grainstone-packstone in figure 15 and south of the thickest portion, respectively. The cross-section lines are shown in figure 15. The north cross section in figure 17 shows two thick grainstone/packstone units; the upper one is partially eroded. Eastward in S-27 the units thin and become predominantly wackestone/mudstone. The south cross section in figure 18 shows thinned carbonate units that are predominantly mudstone/wackestone. In general, two shoaling sequences are represented in the Maquoketa; these are shoaling-upward cycles of dolomitization and deposition combined. The cross sections indicate two shoaling cycles: basal shales capped by dolomite.

Figure 19 shows an example of a reflection seismic line across a small normal fault (Heigold 1990). The Maquoketa section in that reflection line represents the first shoaling cycle. The

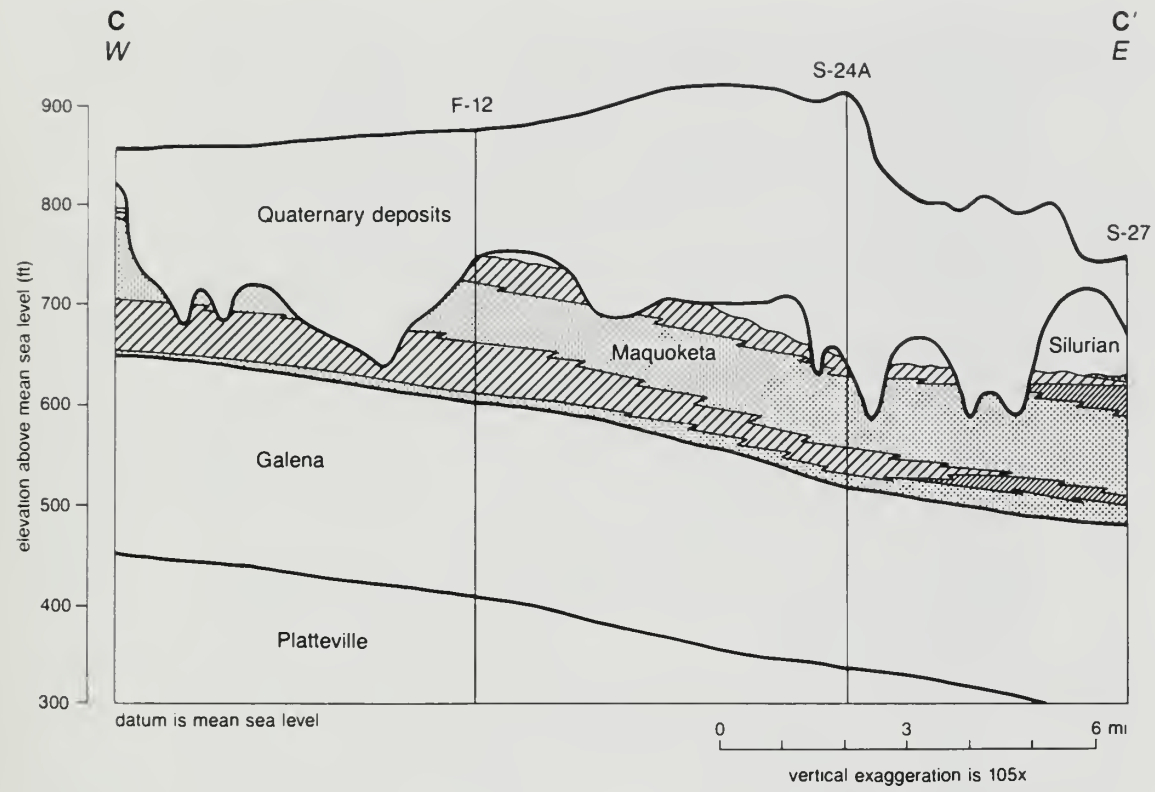

Figure 17 Cross section along a paleotopographic high shows thickened Maquoketa grainstones. Line of cross section is shown on figure 15.

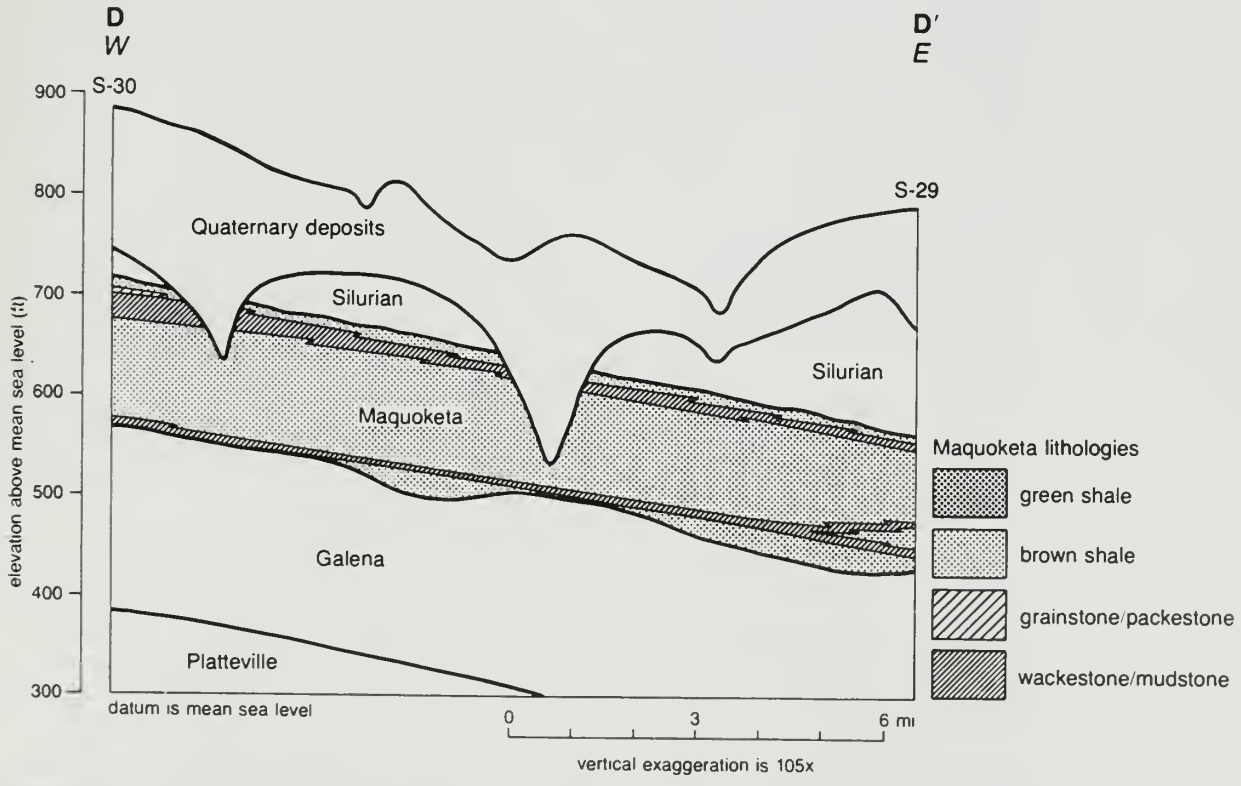

Figure 18 Cross section along a paleotopographic low shows thinned Maquoketa packstones/ grainstones. Line of cross section is shown on figure 15.

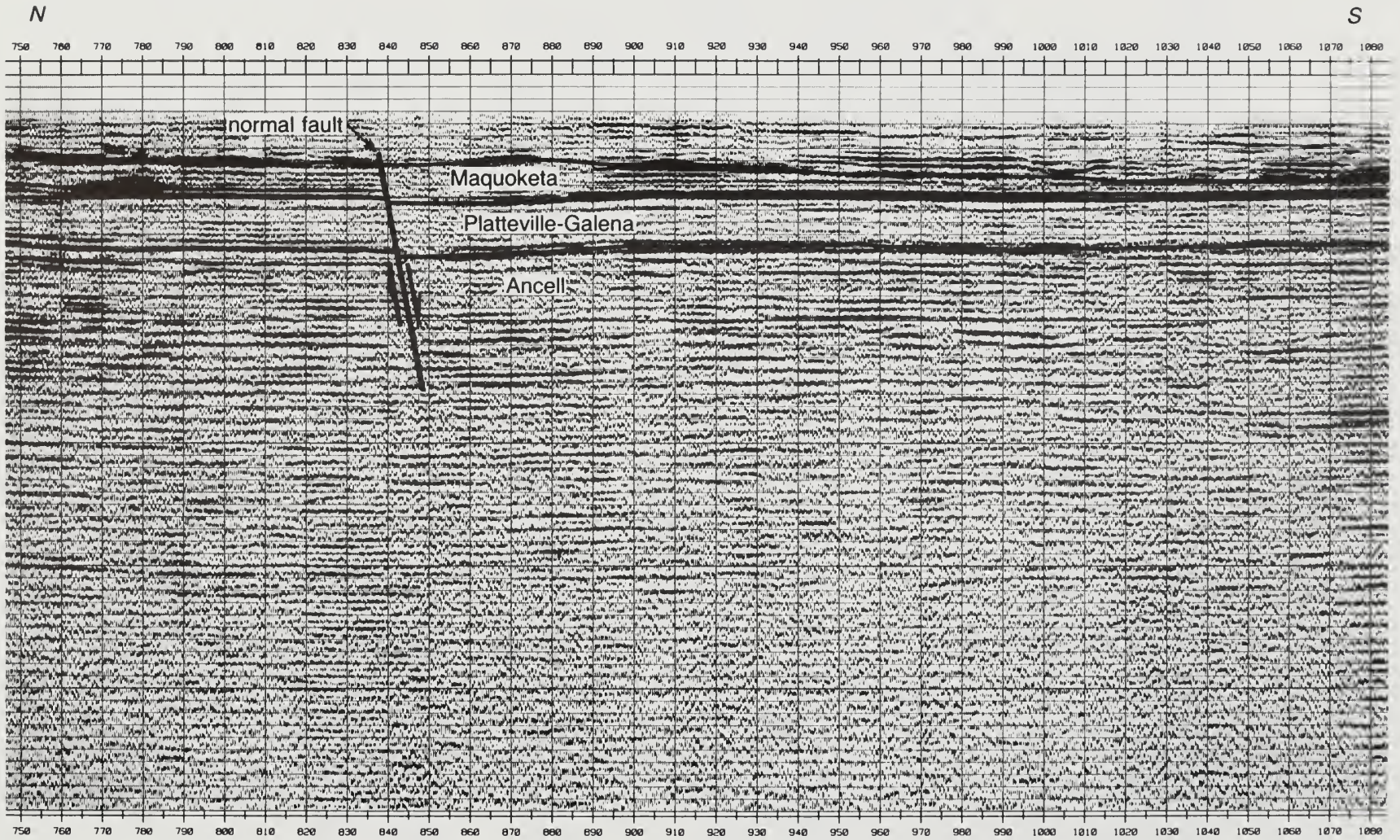

Figure 19 Example of a reflection line across a small normal fault shows accompanying facies distribution (approximately 35 feet of vertical displacement). Compare it to the fault and facies relationships shown in figure 13. (Modified from Heigold 1990.)

shale portion in that reflection line is thickened slightly on the downthrown side. This small faulting may indicate movement concurrent with the end of the Taconic Orogeny. It has been noted that similar features developed shortly after deposition of the Trenton in the area that is now northwestern Ohio (Wickstrom and Gray 1987).

The base of the shoaling sequences is characterized by laminated dark shales typical of a dysaerobic to anaerobic subtidal environment (Kolata and Graese 1983, Cluff et al. 1981). The burrowed dark shales above the laminated zones are suggestive of dysaerobic conditions. The greenish gray shales, common at the tops of the shoaling sequences, are suggestive of more aerobic conditions, regardless of stratigraphic unit. Typically the true Brainard lithology (northern part of the study area) occurs at the top of the sequence above the second shoaling carbonate cycle (Fort Atkinson). However, green shales may be present at the top of the Scales and occasionally within the dark shale sequence (figs. 12 and 13). A thin green shale also typically occurs at the contact between the Galena and the Maquoketa. Brainard lithologies consist of bioturbated, greenish gray shales and varied carbonates that contain abundant macrofossils. These characteristics indicate aerobic, shallower water conditions (perhaps tidal flat) than the deeper water, more anaerobic conditions that produced the laminated to bioturbated olive-gray shales below the shoaling cycles (Kolata and Graese 1983). Some red shales are present at the top of the Maquoketa and included with the Brainard lithology in northeastern Kane, northwestern Du Page, and northwestern Cook Counties. Several wells representative of the Neda in northeastern Kane and western Cook Counties show characteristic Neda lithology with iron-oxide spheroids (Kolata and Graese 1983, p. 30, fig. 32). The Neda has been interpreted to be formed by lateritic weathering (Kolata and Graese 1983). Most of the preserved Neda lies to the northeast of the study area. Laminated carbonates several inches thick occur at the top of the Maquoketa in places; they may be characteristic of a intertidal-supratidal environment.

A map of the elevation of the top of the Maquoketa was prepared but is not shown because the data distribution for this map is marginal. Only the 30 cored holes were plotted. (The map at 1:100,000 scale is filed in the ISGS Map Room.) The map shows a present-day low in T38N, R7-9E. This low appears to lead into the Pleistocene bedrock channel no. 3 in T38N, R6E, in figure 12. The low is located at the approximate position of the Aurora Syncline where the elevation is less than 550 feet.

Silurian Formations (Undifferentiated)

An isopachous map of the Silurian System (fig. 20) shows generally less than 100 feet (30 m) of strata on the eastern margin. The central portion of the map typically shows 50 feet or less of Silurian carbonate where post-Silurian erosion has removed Silurian and Maquoketa rocks. The fact that these Maquoketa rocks no longer show the pattern of thickening along the Aurora Syncline suggests two possibilities: subsidence along this feature during deposition of the Maquoketa Group was not significant or post-Maquoketa erosion strongly modified original thicknesses. The overall distribution of rocks at the bedrock surface, as depicted on this map, is partly controlled by the bedrock topography (R. C. Vaiden and B. B. Curry *in* Graese et al. 1988, p. 19, fig. 15).

SUMMARY

Evaluation of information on the study area as well as regional considerations indicate that the Ordovician Platteville, Galena, and Maquoketa Groups and the basal Silurian carbonate rocks in northeastern Illinois were deposited along a fairly stable shelf in an epicontinental sea. Facies relationships in the Platteville and Galena may reflect slight folding of the carbonate rocks forming an embayment or depression—the Aurora Syncline. Dolomitization occurred north, west, and south of the syncline (fig. 21). The patterns of dolomitization observed in the

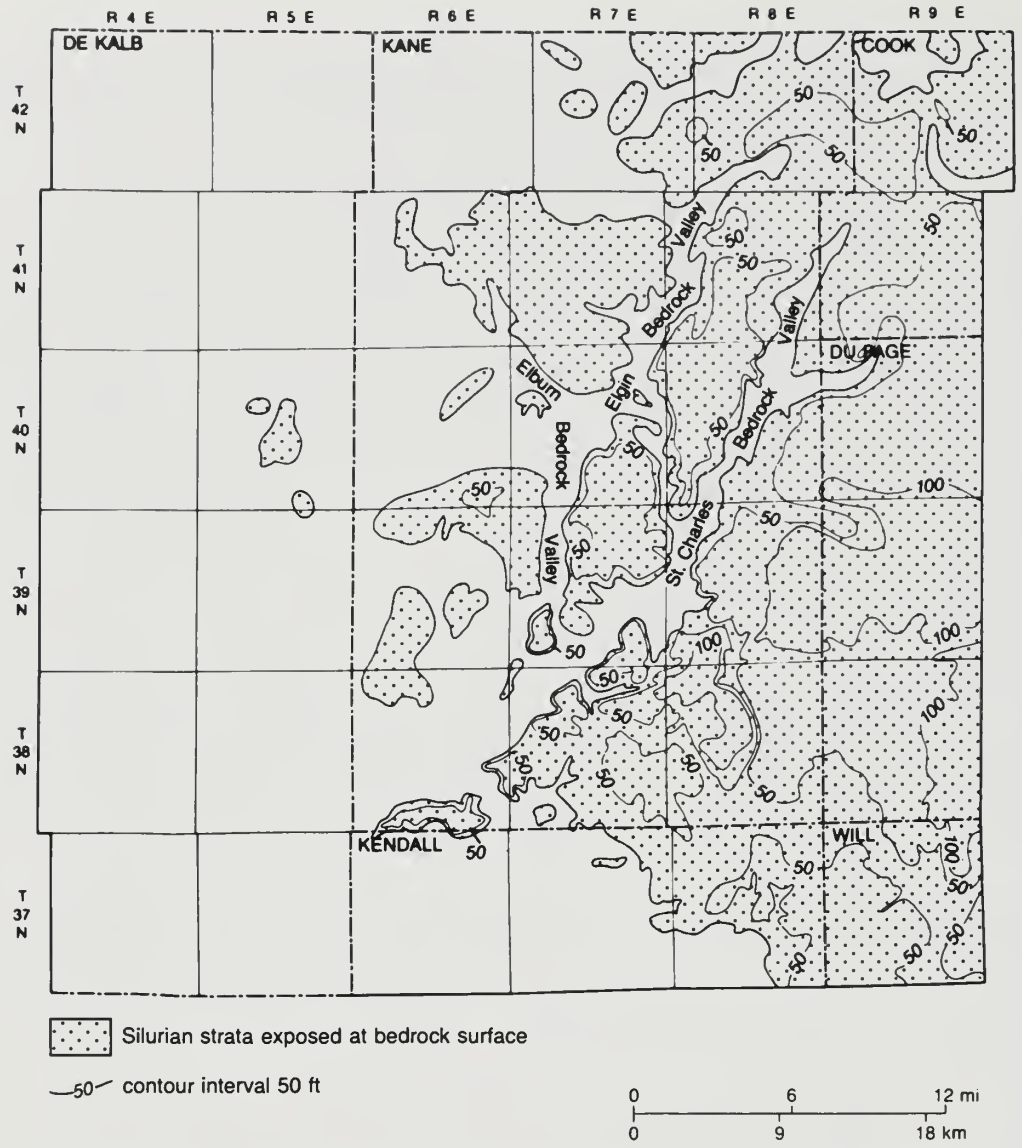

Figure 20 Silurian formations (undifferentiated) isopachous map (modified from Graese et al. 1988; bedrock valleys as indicated in Curry and Seaber 1990). Map is inferred on the basis of 116 datum points.

study area suggest a Dorag model of diagenesis. Limestones deposited within the Aurora Syncline have remained undolomitized. According to the Dorag model (Badiozamani 1983), structurally high areas would be preferentially dolomitized (secondary dolomitization). Primary dolomitization is not a likely hypothesis because the units do not have the characteristics of a supratidal environment, except in rare occurrences in the upper few inches of the Maquoketa. Overall the Maquoketa reflects a subtidal to intertidal environment. Depositional strike was north to south overall, and the sea transgressed from east to west, partially trending the Wisconsin Arch. The Aurora Syncline trends primarily west-east. Other smaller features on contour maps represent undulations on the top of the Galena surface; these are also oriented west-east.

Deposition of the Maquoketa shales indicate an influx of clastic material into the area. The Maquoketa in the study area reflects the distal margin of a clastic wedge of sediment originating from the Appalachian Mobile Belt during the Late Ordovician. Two shoaling cycles can be recognized in the study area, but they are not always complete depending on the structural, paleotopographic configuration of the underlying Galena surface. Typically those

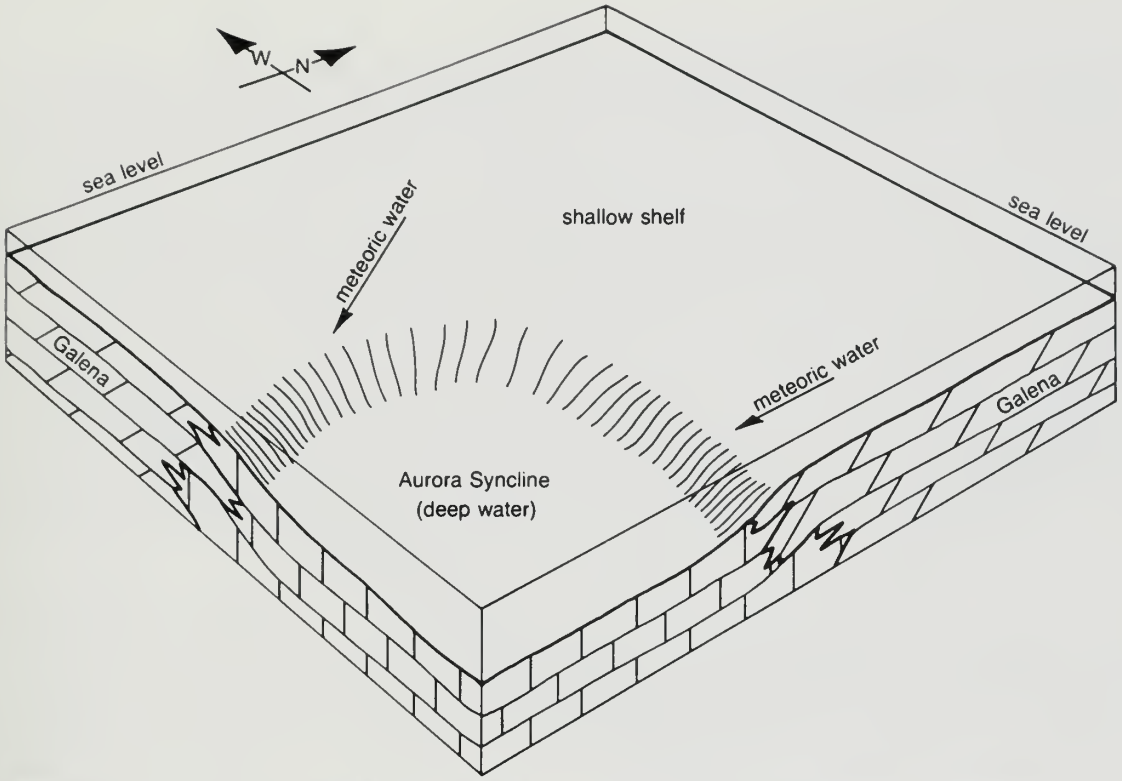

Figure 21 Block diagram of facies relationships and depositional environments of the Galena-Platteville shows limestone facies within the Aurora Syncline.

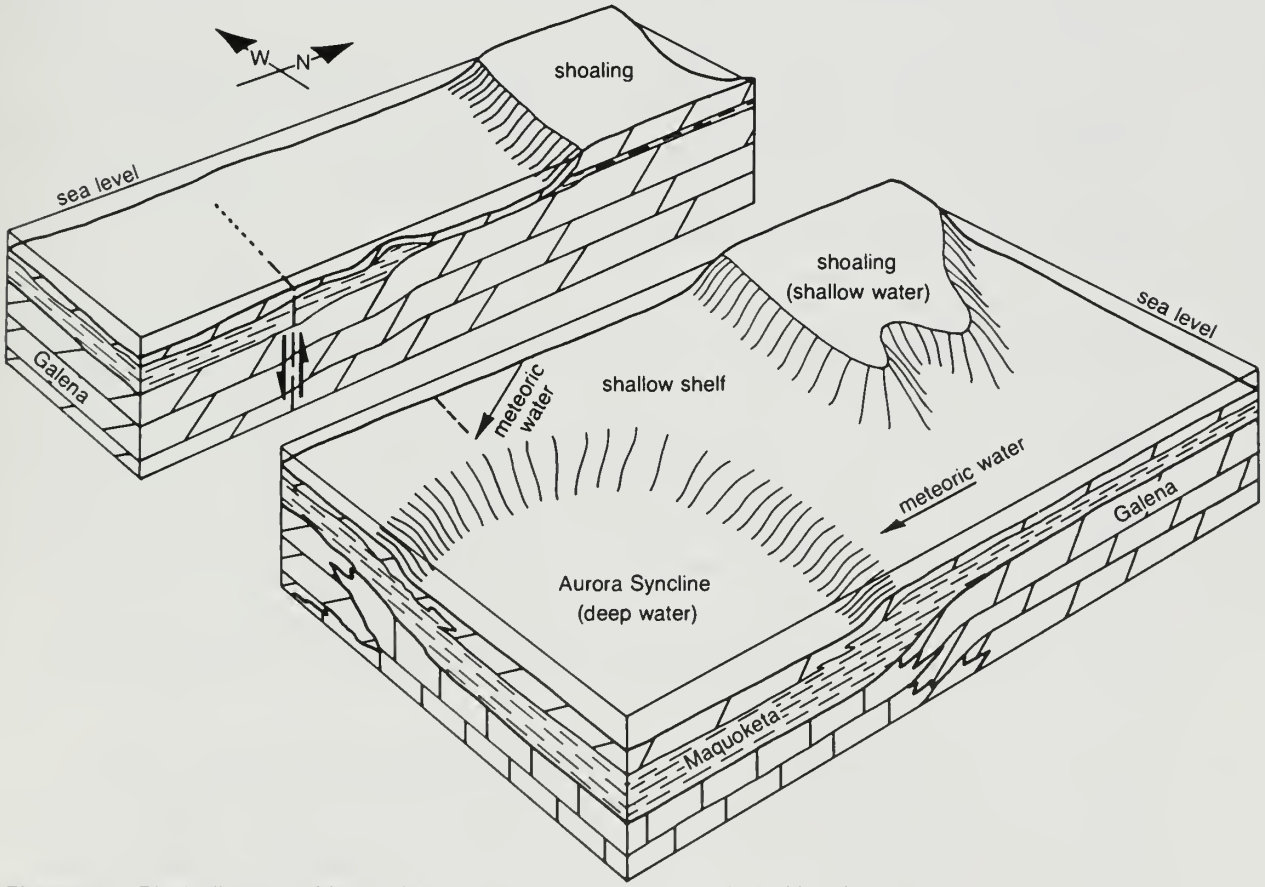

Figure 22 Block diagram of Maquoketa facies relationships and depositional environments shows shoaling carbonates thickening along a paleotopographic high.

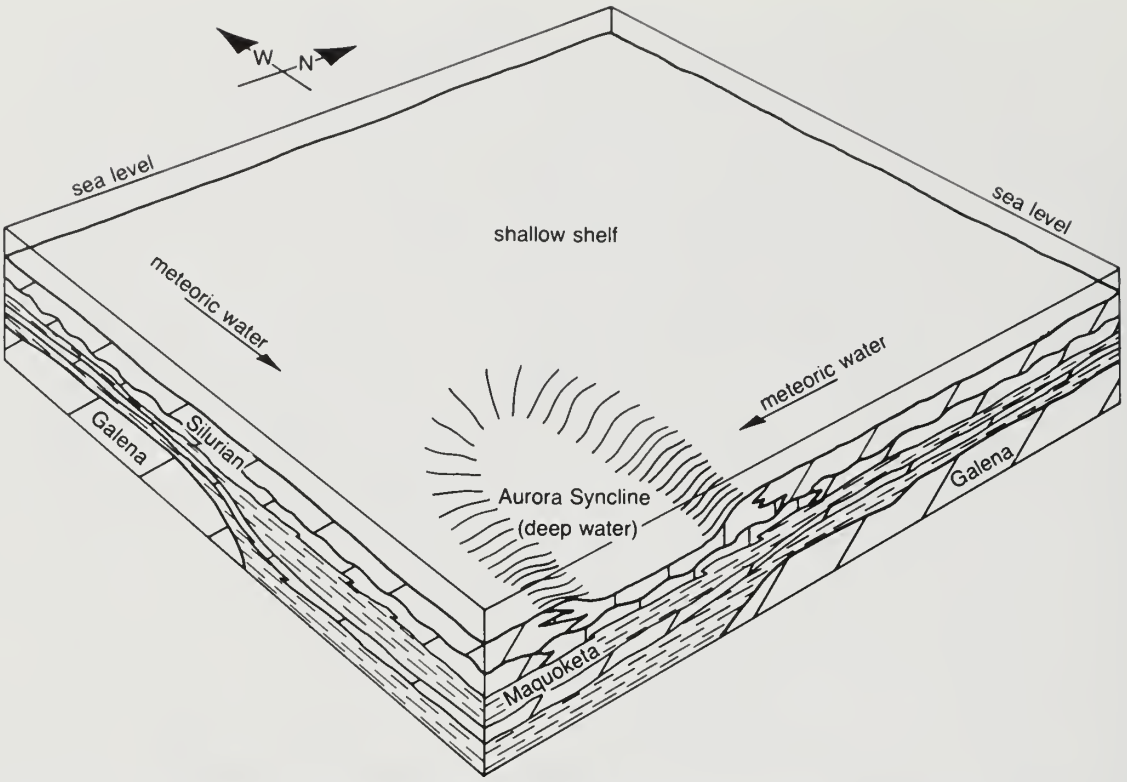

Figure 23 Block diagram of facies relationships and depositional environment—end of second Maquoketa shoaling sequence and Silurian transgression.

cycles are not completed in lows. Although the cycles in the Aurora Syncline consist of mudstone-wackestone, they do not grade upward into the thicker packstone-grainstone sequences typical along the paleohigh north of that area. Glacio-eustatic changes in sea level in combination with local, subtle, structural movements superimposed on a slightly irregular paleotopographic surface are the suggested explanation for the occurrence, thickness, and distribution of facies within the Maquoketa in the study area.

The relative thickness of coarse-grained, dolomitized carbonate bodies increases on the paleostructural/paleotopographic high in the northern part of the study area. Fine-grained shaly dolomites and limestones predominate in the paleotopographically lower areas within the Aurora Syncline. The component of shale to carbonate also increases in paleolows, whereas the coarse-grained carbonate component increases on the paleohighs. The coarse-grained carbonates are interpreted as shoals at wave base, whereas the dark shales and carbonate mudstones/wackestones are interpreted as deposits below wave base. Minor faulting (perhaps syndepositional) occurring during the Galena to first Maquoketa shoaling cycle is most likely related to the Taconic Orogeny (fig. 13 and 19). Similar features have been noted to occur shortly after deposition of the Trenton in northwestern Ohio (Wickstrom and Gray 1987). The Brainard Formation, although not extensive in the study area, is probably representative of intertidal mud flats. Some rare, finely laminated carbonates at the top of some cores may be characteristic of a supratidal environment.

The Maquoketa is bounded at the top by a pre-Silurian unconformity defined by a distinct change in lithology from typically greenish gray shales (Maquoketa) to yellowish gray carbonates (Silurian). Where the Wilhelmi is present, a lithologic change from dark gray shales (Wilhelmi) to green shales (Maquoketa) can be recognized (Willman and Atherton 1975). An angular unconformity, which can be recognized between the Brainard and the overlying Silurian and the Neda (considered a laterite), is suggestive of subaerial exposure (Kolata and Graese

1983). However, in low areas, the unconformity is not readily identifiable and may indicate more or less continuous deposition. This would be likely in the Aurora Syncline, but may not be the case in the higher paleotopographic areas.

The Silurian carbonates are partially to completely eroded in the study area, thus any conclusions based on the stratigraphic evidence is very speculative (fig. 23). Limestones are confined to a much smaller region than underlying units. Up-section the limestone in the low in the paleotopography diminished from 210 square miles (336 km^2) to less than 20 square miles (32 km^2). In the Silurian rocks, however, no increase in thickness occurs that indicates a large low in the underlying surface. The elevation of the underlying Maquoketa surface is, however, still about 50 feet (15 m) lower than in the surrounding area. The Silurian isopachous map partially reflects pre-Pleistocene erosion. Along the Galena outcrop belt, west-east oriented elongate bedrock valleys (figs. 9 and 10) were incised prior to the Pleistocene, parallel the local west-east structural trends in the area, and may be related to minor folding, faulting, or fracturing.

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REFERENCES

Amaral, E. J., and W. A. Pryor, 1976, Depositional environment of the St. Peter Sandstone deduced by textural analysis: Journal of Sedimentary Petrology, v. 47, p. 32-52.

Badiozamani, K., 1973, The Dorag dolomitization model—application to the Middle Ordovician of Wisconsin: Journal of Sedimentary Petrology, v. 43, p. 965-984.

Berkey, C. P., 1906, Paleogeography of St. Peter time: Geological Society of America Bulletin, v. 17, p. 229-250.

Bretz, J. H., 1938, Caves in the Galena Formation: Journal of Geology, v. 46, no. 6, p. 828-841.

Bretz, J. H., 1939, Geology of the Chicago Region: Illinois State Geological Survey, Bulletin 65, 132 p.

Bretz, J. H., 1940, Solution cavities in the Joliet Limestone of Northeastern Illinois: Journal of Geology, v. 48, no. 4, p. 337-384.

Buschbach, T. C., 1964, Cambrian and Ordovician Strata of Northeastern Illinois: Illinois State Geological Survey, Report of Investigations 218, 90 p.

Buschbach, T. C., R. T. Cyrier, and G. E. Heim, 1982, Geology and deep tunnels in Chicago, Reviews in Engineering Geology: Geological Society of America, Vol. V, p. 41-54.

Cluff, R. M., M. L. Reinbold, and J. A. Lineback, 1981, The New Albany Shale Group in Illinois: Illinois State Geological Survey, Circular 518, p. 83 p.

Cohee, G. V., and 15 others, 1962, Tectonic Map of the United States: American Association of Petroleum Geologists, sheets 1 and 2, scale 1:2,500,000.

Collinson, C., M. L. Sargent, J. R. Jennings, 1988, Illinois Basin region, *in* L. L. Sloss (editor), Sedimentary Cover—North American Craton: U.S., The Geology of North America, v. D2, p. 383-426.

Curran, L. M., S. B. Bhagwat, C. A. Hindman, 1988, Disposal Alternatives for Material to Be Excavated from the Proposed Site of the Superconducting Super Collider in Illinois: Illinois State Geological Survey, Environmental Geology Notes 125, 17 p.

Curry, B. B., A. M. Graese, M. J. Hasek, R. C. Vaiden, R. A. Bauer, D. A. Schumacher, K. A. Norton, W. G. Dixon, Jr., 1988, Geological-Geotechnical Studies for Siting the Superconducting Super Collider in Illinois: Results of the 1986 Test Drilling Program: Illinois State Geological Survey, Environmental Geology Notes 122, 108 p.

Curry, B. B., and P. R. Seaber, 1990, Hydrogeology of Shallow Groundwater Resources, Kane County, Illinois: ISGS Contact/Grant Report 1990-1, 37 p.

Dapples, E. C., 1955, General lithofacies relationship of the St. Peter Sandstone and the Simpson Group: American Association of Petroleum Geologists Bulletin, v. 39, p. 444-467.

Delgado, D. J., 1983, Deposition and diagenesis of the Galena Group in the Upper Mississippi Valley, *in* D. J. Delgado, Ordovician Galena Group of the Upper Mississippi Valley—Deposition Diagenesis and Paleoecology: Great Lakes Section, Society of Economic Paleontologists and Mineralogists, Guidebook for the 13th Annual Field Conference, September 30 - October 2, 1983, p. A1-A17.

Droste, J. B., and R. H. Shaver, 1983, Atlas of Early and Middle Paleozoic Paleogeography of the Southern Great Lakes Area: Indiana Department of Natural Resources, Geological Survey, Special Report 32, 32 p.

Dunham, R. J., 1962, Classification of carbonate rocks according to depositional texture, *in* W. E. Ham (editor), Classification of Carbonate Rocks: American Association of Petroleum Geologists, Memoir 1, p. 108-121.

Ekblaw, G. E., 1938, Kankakee Arch in Illinois: Geological Society of America, Bulletin, v. 49, no. 9, p. 1425-1430.

Fara, D. R., and B. D. Keith, 1989, Depositional facies and diagenetic history of the Trenton Limestone in northern Indiana, *in* B. D. Keith (editor), Upper Ordovician Rocks of Eastern North America—Deposition, Diagenesis, and Petroleum Occurrence: American Association of Petroleum Geologists, Studies in Geology 29, p. 277-298.

Fisher, J. H., M. W. Barratt, J. B. Droste, and R. H. Shaver, 1988, Michigan Basin, *in* L. L. Sloss (editor), Sedimentary Cover—North American Craton: U.S., The Geology of North America, p. 361-382.

Fraser, G. S., 1976, Sedimentology of a middle Ordovician quartz arenite-carbonate transition in the upper Mississippi Valley: Geological Society of America, Bulletin, v. 86, p. 833-845.

Geological Society of America, Rock-Color Chart, 1984, prepared by the Rock-Color Chart Committee and distributed by Geological Society of America, Boulder, CO.

Graese, A. M., 1988, Facies distribution within the Maquoketa and Galena-Platteville Groups and their relationship to Ordovician structural history in northeastern Illinois: Geological Society of America, North-Central Section, Abstracts with Programs, v. 20, no. 5, March 1988, p. 345.

Graese, A. M., R. A. Bauer, B. B. Curry, R. C. Vaiden, W. G. Dixon, Jr., and J. P. Kempton, 1988, Geological-Geotechnical Studies for Siting the Superconducting Super Collider in Illinois: Regional Summary: Illinois State Geological Survey, Environmental Geology Notes 123, 100 p.

Graese, A. M., and Kolata, D. R., 1985, Lithofacies distribution within the Maquoketa Group (Ordovician) in northeastern Illinois: Geological Society of America, North-Central Section, Abstracts with Programs, v. 17, no. 5, March 1985, p. 291.

Gregg, J. M., 1982, The origin of xenotopic dolomite texture: Ph.D. dissertation, Michigan State University, 151 p.

Harza Engineering Company, 1975, Mainstream tunnel system, Tunnel and Reservoir Plan: Geotechnical Design Report prepared for Metropolitan Sanitary District of Greater Chicago, Appendix A. Geology and Hydrogeology, 90 p.

Harza Engineering Company, 1984, Mainstream system, Tunnel and Reservoir Plan, Volume II. Geology and Hydrogeology: Construction Report prepared for Metropolitan Sanitary District of Greater Chicago, 94 p.

Harza Engineering Company with Illinois State Geological Survey, 1988, Geotechnical Summary to the Proposal to Site the Supercoducting Super Collider in Illinois: Illinois State Geological Survey, Special Reprint, 48 p.

Heigold, P. C., 1990, Seismic Reflection and Seismic Refraction Surveying in Northeastern Illinois: Illinois State Geological Survey, Environmental Geology 136, 52 p.

Hughes, G. M., P. Kraatz, and R. A. Landon, 1966, Bedrock Aquifers of Northeastern Illinois: Illinois State Geological Survey, Circular 406, 15 p.

Jacobson, S. R., J. R. Hatch, S. C. Teerman, and R. A. Askin, 1988, Middle Ordovician organic matter assemblages and their effect on Ordovician-derived oils: American Association of Petroleum Geologists, Bulletin, v. 72, no. 9, p. 1090-1100.

Keith, B. D., 1985, Facies, diagenesis, and the upper contact of the Trenton Limestone of northern Indiana, *in* K. R. Cercone and J. M. Budai (editors), Ordovician and Silurian Rocks of the Michigan Basin and Its Margins: Michigan Basin Geological Society, Special Paper 4, p. 15-22.

Kempton, J. P., R. C. Vaiden, D. R. Kolata, P. B. DuMontelle, M. M. Killey, and R. A. Bauer, 1985, Geological-Geotechnical Studies for Siting the Superconducting Super Collider in Illinois: Preliminary Geological Feasibility Report: Illinois State Geological Survey, Environmental Geology Notes 111, 63 p.

Kempton, J. P., R. A. Bauer, B. B. Curry, W. G. Dixon, Jr., A. M. Graese, P. C. Reed, M. L. Sargent, and R. C. Vaiden, 1987a, Geological-Geotechnical Studies for Siting the Super Collider in Illinois: Results of the Fall 1984 Test Drilling Program: Illinois State Geological Survey, Environmental Geology Notes 117, 102 p.

Kempton, J. P., F. A. Bauer, B. B. Curry, W. G. Dixon, Jr., A. M. Graese, P. C. Reed, and R. C. Vaiden, 1987b, Geological Studies for Siting the Superconducting Super Collider in Illinois: Results of the Spring 1985 Test Drilling Program: Illinois State Geological Survey, Environmental Geology Notes 120, 108 p.

Kolata, D. R., T. C. Buschbach, and J. D. Treworgy, 1978, The Sandwich Fault Zone of Northern Illinois: Illinois State Geological Survey, Circular 505, 26 p.

Kolata, D. R., and A. M. Graese, 1983, Lithostratigraphy and Depositional Environments of the Maquoketa Group (Ordovician) in Northern Illinois: Illinois State Geological Survey, Circular 528, 49 p.

Kolata, D. R., J. K. Frost, and W. D. Huff, 1986, K-bentonites of the Ordovician Decorah Subgroup, Upper Mississippi Valley: Correlation by Chemical Fingerprinting: Illinois State Geological Survey, Circular 537, 30 p.

Land, L. S., 1973, Holocene meteoric dolomitization of Pleistocene limestones, North Jamaica: Sedimentology, v. 20, p. 411-424.

Mazzullo, J. H., and R. Ehrlich, 1983, Grain-shape variation in the St. Peter Sandstone: A record of eolian and fluvial sedimentation of an Early Paleozoic cratonic sheet sand: Journal of Sedimentary Petrology, v. 50, p. 63-70.

Mazzullo, J. H., and R. Ehrlich, 1987, The St. Peter Sandstone of Southeastern Minnesota: Mode of Deposition: Middle and Late Ordovician Lithostratigraphy and Biostratigraphy of the Upper Mississippi Valley: University of Minnesota, Report of Investigations 35, 232 p.

McHarque, T. T., and R. C. Price, 1982, Dolomite from clay in argillaceous or shale-associated marine carbonates: Journal of Sedimentary Petrology, v. 52, no. 3, p. 873-886.

McGinnis, L. D., 1966, Crustal Tectonics and Precambrian Basement in Northeastern Illinois: Illinois State Geological Survey, Report of Investigations 219, 29 p.

Mikulic, D. G., M. L. Sargent, R. D. Norby and D. R. Kolata, 1985, Silurian Geology of the Des Plaines River Valley, Northeastern Illinois: Illinois State Geological Survey, Guidebook 17, 56 p.

Mikulic, D. G., 1989, The Chicago stone industry: A historical perspective, *in* R. E. Hughes and T. C. Bradbury (editors), Proceedings of the 23rd Forum of Geology of Industrial Minerals, May 11-15, 1987: Illinois State Geological Survey, Illinois Minerals 102, p. 83-89.

North American Commission on Stratigraphic Nomenclature, 1983, North American Stratigraphic Code: American Association of Petroleum Geologists, Bulletin, v. 67, no. 5, 1491 p.

Palmquist, R. C., 1969, The configuration of the Prairie du Chien-St. Peter contact in southwestern Wisconsin: An example of an integrated geological-geophysical study: Journal of Geology, v. 77, p. 694-702.

Pirtle, G. W., 1932, Michigan structural basin and its relationship to surrounding areas: American Association of Petroleum Geologists, Bulletin, v. 16, no. 2, p. 145-152.

Sloss, L. L., 1963, Sequences in the cratonic interior of North America: Geological Society of America, Bulletin, v. 74, p. 93-114.

Sloss, L. L. 1988, Tectonic evolution of the craton in Phanerozoic time, *in* L. L. Sloss (editor), Sedimentary Cover—North American Craton: U.S., The Geology of North America, v. D2, p. 25-51.

State of Illinois, 1987, Geology and Tunneling, Proposal to Site the Superconducting Super Collider in Illinois, Vol. 3, 67 p.

Swann, D. H., and H. B. Willman, 1961, Megagroups in Illinois: American Association of Petroleum Geologists, Bulletin, v. 45, p. 471-483.

Templeton, J. S., and H. B. Willman, 1952, Central northern Illinois: Illinois State Geological Survey, Guidebook 2, 47 p.

Templeton, J. S., and H. B. Willman, 1963, Champlainian Series (Middle Ordovician) in Illinois: Illinois State Geological Survey, Bulletin 89, 260 p.

Vaiden, R. C., M. J. Hasek, C. R. Gendron, B. B. Curry, A. M. Graese, and R. A. Bauer, 1988, Geological-Geotechnical Studies for Siting the Superconducting Super Collider in Illinois: Results of Drilling Large-Diameter Test Holes in 1986: Illinois State Geological Survey, Environmental Geology Notes 124, 58 p.

Whitaker, S. T., 1988, Silurian Pinnacle Reef Distribution in Illinois: Model for Hydrocarbon Exploration: Illinois State Geological Survey, Illinois Petroleum 130, 32 p.

Wickstrom, L. H., and J. D. Gray, 1987, Structural Geology of Northwestern Ohio: New Looks at Old Horizons: American Association Petroleum Geologists, Eastern Section Conference: 44 p.

Willman, H. B., and others, 1967, Geologic Map of Illinois: Illinois State Geological Survey, scale 1:500,000.

Willman, H. B., 1971, Summary of the Geology of the Chicago Area: Illinois State Geological Survey, Circular 460, 77 p.

Willman, H. B., 1973, Rock Stratigraphy of the Silurian System in Northeastern and Northwestern Illinois: Illinois State Geological Survey, Circular 479, 55 p.

Willman, H. B., and Elwood Atherton, 1975, Silurian System, *in* H. B. Willman, Elwood Atherton, T. C. Buschbach, Charles Collinson, J. C. Frye, M. E. Hopkins, J. A. Lineback, and J. Simon, Handbook of Illinois Stratigraphy: Illinois State Geological Survey, Bulletin 95, p. 87-104.

Willman, H. B., and T. C. Buschbach, 1975, Ordovician System, *in* H. B. Willman, Elwood Atherton, T. C. Buschbach, Charles Collinson, J. C. Frye, M. E. Hopkins, J. A. Lineback, and J. Simon, Handbook of Illinois Stratigraphy: Illinois State Geological Survey, Bulletin 95, p. 47-94.

Willman, H. B., and D. R. Kolata, 1978, The Platteville and Galena groups in northern Illinois: Illinois State Geological Survey, Circular 502, 75 p.

Willman, H. B., and J. N. Payne, 1942, Geology and mineral resources of Marseilles, Ottawa, and Streator Quadrangles: Illinois State Geological Survey, Bulletin, 388 p.

Willman, H. B., J. A. Simon, B. M. Lynch, V. A. Langenheim, 1968, Bibliography and Index of Illinois Geology through 1965: Illinois State Geological Survey, Bulletin 92, 373 p.

Wilson, J. L., 1975, Carbonate facies in Geologic History: Springer-Verlag, New York, Heidelberg, Berlin, 471 p.

Witzke, B. J., and D. R. Kolata, 1988, Changing structural and depositional patterns, Ordovician Champlainian and Cincinnatian Series of Iowa-Illinois, *in* G. A. Ludvigson and B. J. Bunker (editors), New Perspectives of the Paleozoic History of the Upper Mississippi Valley, 18th Annual Field Conference of the Great Lakes Section, Society of Economic Paleontologists and Mineralogists, Bellevue, Iowa, October 1-2, 1988: Iowa Department of Natural Resources Geological Survey, Bureau Guidebook 8, 245 p.